THE OBJECT LESSON BOOK

By GEORGE RICKS B.Sc. (Lond.)

NATURAL HISTORY OBJECT LESSONS

A Manual for Teachers and Pupil Teachers

OBJECT LESSONS AND HOW TO GIVE THEM

First Series for Primary Schools

OBJECT LESSONS AND HOW TO GIVE THEM

Second Series for Intermediate and Grammar Schools

OBJECT LESSONS

AND HOW TO GIVE THEM

Second Series

FOR INTERMEDIATE AND GRAMMAR SCHOOLS

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INTRODUCTION TO

OBJECT LESSONS

AND HOW TO GIVE THEM.

OUR knowledge of the material world is obtained through the senses. The organs of sense are the eye, the ear, the nose, the tongue and palate, and the nerves of touch located in the skin. The special nerves of these organs are acted on by things external to the body; the effect is conveyed to the brain ; and mental impressions or ideas are the result. Thus a red colour acting on the retina, the sound from a whistle acting on the auditory nerves, or the smell of an onion on the olfactory nerves produces a definite mental impression. The five sensory organs, then, are so many doors and windows by which knowledge enters the mind.

There is, however, another source of knowledge of material bodies. In this case the mental impressions are derived from within the body, and are due to muscular exertion. It is by muscular feeling that we estimate the amount of force required to overcome resistance. Thus we get ideas of elasticity and weight from the amount of active energy put forth by the muscles to overcome inertia in the one case and gravitation in the other. If a weight is placed in the hand we are conscious of a certain amount of force expended to keep it from falling ; if the weight is increased we are conscious of an increased expenditure of muscular energy.

The mental impressions, formed by and through the senses, including muscular feeling, are called *sensations*.

By the organs of sense we are said to *perceive*, or to make mental notes of external bodies, and these mental notes we

call *perceptions.* Perception is the first step in knowledge: attentive perception leads to *observation*; observation is the forerunner of *comparison*; while comparison is the basis of *classification*; and these together constitute the foundation of all knowledge.

The primary purpose of lessons on common objects and natural phenomena is to cultivate the senses, to train to habits of attention, intelligent observation, and accurate comparison, and so to lead up to the higher processes of the mind—reason and judgment. Of course the acquisition of information is an important aim; but the object lesson is designed to assist and guide the child to discover properties of things, and thus acquire knowledge for himself, rather than to pour information into his mind like wheat into a sack.

Mental impressions are formed at a very early period of childhood. A bright light or a shining object attracts attention before the child has acquired the power of taking hold with its hands; and a certain amount of discrimination, enabling it, for instance, to distinguish the face of its mother from that of a stranger, quickly follows. The power of recognising resemblances and differences rapidly increases, new ideas are as rapidly acquired; and when the child enters school, he enters it with his perceptive faculties, to a certain extent, cultivated, and with his mind a treasury of simple ideas.

The natural course for the teacher would seem to be to gather up into something like order, and to perfect, that which has been so far imperfectly accomplished; and then, starting from this as a basis, to evolve a systematic course of training, proceeding step by step in a natural order, each step being a logical sequence of the preceding. Further, the teacher who would best succeed must take childhood's method of imbibing knowledge and adapt it to her own use. Restless activity, insatiable curiosity, and love of imitation

characterize childhood. What the child sees he wants to know about, to handle, and examine, and, if possible, to take to pieces, or otherwise experiment upon; what he sees done he wants to do, and if opportunity be not found for the indulgence of his natural activity, he will find the opportunity for himself. An object lesson, then, besides fulfilling some definite purpose in training the perceptive faculties, should provide something for the children to *do* to satisfy their innate activity, something to *examine* and *discover* to arouse their curiosity, and something to *copy* to gratify their desire for imitation. Herein lies the secret of securing attention, of begetting a state of vigorous mental activity, and of associating pleasure with instruction.

The selection of lessons, and their adaptation to the capacities of the scholars, or to their different stages of advancement, is another point of fundamental importance. A child of four years of age is a different being, intellectually, from a child of seven; and a lesson suited to the capacity of the one must be totally unsuited to the mental condition of the other. The mental faculties of a child are strengthened and invigorated by proper exercise, but are weakened and depressed by being exercised on subjects beyond his powers of comprehension. To graduate the lessons to the mental condition and previous training of the scholars necessitates a complete system. It is not sufficient to select a lesson at random, no matter how skilfully it may be handled. Each lesson, whilst fulfilling its own special purpose, must form a link in the chain, a unit in the whole.

Nor is the *method* of giving the individual lessons of less importance than their selection and adaptation. Occasional information given about things of every-day life does not serve the distinctive aim of object lessons. To be a passive recipient of information gives no pleasure to a child. To hold an object before it, and enumerate its general properties—what it is composed of, or where or how it is made—and

then to get the information returned by questioning, is at best but a mere exercise of the memory; it does nothing in the way of exercising and developing the more important mental powers.

"To *tell* a child this, and to *show* the other, is not to teach it how to observe, but to make it a mere recipient of another's observations — a proceeding which weakens rather than strengthens its powers of self-instruction, which deprives it of the pleasure resulting from successful activity, which presents this all-attractive knowledge under the aspect of formal tuition, and which thus generates that indifference and even disgust with which these object lessons are sometimes regarded. On the other hand, to pursue the true course is simply to guide the intellect to its appropriate food, and to habituate the mind from the beginning to that practice of self-help which it must ultimately follow. Children should be led to make their own investigations and to draw their own inferences. They should be *told* as little as possible, and induced to *discover* as much as possible." *

Having formed new ideas of things by the method of observation and experiment under the guiding hand of the teacher, our next step is to endeavour to fix these ideas in the minds of the children by means of language. But in every case words must *follow* ideas; in fact, terms should not be given till the necessity for them is felt. Thus, suppose "a liquid" to be the subject of the lesson. The children are led by experiment on several liquid bodies to note that they all have certain common properties—such as flowing in a stream, finding the lowest level, spreading out and filling up hollows, easily flowing in drops, having no definite shape, but taking the shape of the vessel into which they are poured—and the necessity is felt for one term which at once embodies all these properties. The extension of the children's vocabulary in this way is one of the minor advantages of object lessons;

* Herbert Spencer.

and further, to secure freedom and accuracy in speech, the children should be encouraged to answer all questions, as far as possible, in complete sentences, or at any rate in complete phrases.

The teacher may commence object lessons by taking some familiar object—such, for instance, as the black-board—and lead the children to observe its colour, shape, substance, surface, and so on; but then we have so many properties in combination that the scholars are not likely to get very clear notions of any. It is desirable, therefore, if not actually necessary, that lessons on objects should be preceded by a special training in colour, form, size, weight, hardness, and others of the more conspicuous properties of bodies. Lessons on objects may then be introduced gradually, and, to a large extent, they may be made to constitute simple practice in the application of previously acquired knowledge.

In dealing with the properties or qualities of objects, those only should be dwelt upon which render the objects valuable for the several uses in which they are employed. Thus, all children are alive to the fact that we cannot see through sponge, cork, india-rubber, or leather; but to stop to describe these objects as *opaque* is a waste of time. On the other hand, although the children know equally well that we can see through glass, its property of transparency must be made a cardinal point in a lesson on glass, because it is this property which makes glass specially useful.

INTRODUCTION

TO

OBJECT LESSONS

FOR JUNIOR AND SENIOR SCHOOLS.

"The practice of every art implies a certain knowledge of natural causes and effects, and the improvement of our arts and industries depends upon our knowing the PROPERTIES of natural objects which we can get hold of and put together."

"No line can be drawn between *common knowledge* of things and *scientific knowledge*, nor between *common reasoning* and *scientific reasoning*. In strictness all accurate knowledge is *science*, and all exact reasoning is scientific reasoning."

"The method of OBSERVATION and EXPERIMENT by which such great results are obtained in science, is identically the same as that which is employed by every one, every day of his life, but refined and rendered more precise."

"The way to science lies through COMMON KNOWLEDGE, we must extend that knowledge by careful OBSERVATION and EXPERIMENT, and learn how to state the results of our investigations accurately, in general rules or laws of nature, and we must learn how to reason accurately from these rules, and thus arrive at rational explanations of natural phenomena, which may suffice for our guidance in life." *

On these principles laid down by Professor Huxley the following simple lessons on natural objects, and natural phenomena have been constructed.

* Professor Huxley.

Their primary purpose is to develop the faculties of the mind, to quicken the intelligence, to train to habits of accurate observation, exact comparison, and sound reasoning, and to excite an interest in all those objects with which we daily come in contact, and those natural phenomena which constantly appear before our eyes.

The lessons are suggestive rather than exhaustive; some are little more than outlines; a few are worked out more fully as models for young teachers.

The experiments are numerous and interesting, yet simple and inexpensive.

The lessons of the First Stage* deal with the more common properties of solids, and show how these properties make them specially useful in the arts and industries. They are lessons almost entirely of observation, experiment, and comparison. Those of the Second Stage deal similarly with the properties of liquids and gases illustrated by *water* and *air*. The Third and higher stages demand a closer observation; the reasoning faculties are gradually brought more fully into exercise; and the simplest facts and laws of nature are explained in the simplest possible way.

* The standards for which the stages are suited must depend in a great measure on how far the children have been trained in the infant school, but, generally, Stage I. will be suitable for Standard II., Stage II. for Standard III., and so on. Lessons suitable for Standard I. will be found in "Object Lessons, and How to give them, *First Series, for primary schools.*"

FIRST STAGE.

FIRST STAGE.

LESSON I.

SOLID AND LIQUID.

ARTICLES for illustration: any specimens of well-known solid bodies, water, a piece of sponge, and one or two glass vessels.

I. To show that the minute particles of which solids are built up are held more or less firmly together.

Experiment 1. Take two lumps of loaf sugar; and, rubbing them together, show that the lumps are made up of *grains*.

Exp. 2. Crush or pound the grains to show that these may be divided into smaller bits as fine as flour or dust, and too small to be easily seen as separate *particles*.

Exp. 3. Rub lumps of chalk together, to show how extremely fine are the tiny *particles* of which chalk is made.

Exp. 4. Hand a small cubical lump of loaf sugar, or a piece of brick, to a scholar, and ask him to separate it into tiny bits. He fails. Why? The sugar, or brick, is too hard. The *grains*, or *particles*, are held together too firmly.

II. To show that water and oil are also composed of minute particles; but that these are held together less firmly than are the grains of sugar and salt

Exp. 5. Take some water in a tumbler, and sprinkle a little on the floor, or blow a little through a syringe, to show the tiny drops.

Exp. 6. Into a test-tube three-parts full of water pour a single drop of olive oil. Shake well; the single drop is divided into thousands of tiny drops, giving the water a milky appearance; but the drops are too small to be seen separately.

"Now which is the more easy to divide, the oil and the water into tiny drops, or the sugar and salt into grains?" *The water and oil.* "And why?" *Because the drops of oil and water are not held so firmly together as are the grains in the sugar and in the salt.*

"Here are pieces of stone and wood. You can handle them, pass them round, throw them up, and they are not altered. Now, can we take a piece of this water out of the glass and pass it round the class? No; it would break into drops at once, and fall on the floor."

"I want you to remember that *all those things in which the tiny particles are held firmly together we call* SOLIDS*; and that all those things which are made up of tiny drops not held firmly together we call* LIQUIDS."

III. To show that solids have shapes of their own; but that liquids, having no shapes of their own, take the shapes of the vessels in which they are placed.

The teacher may proceed somewhat as follows:—

"Here is a small block of wood.* What is its shape?" *A cube.*

"I put it in this tumbler; is its shape altered?" *No.*

"What shape has it still?" *A cube.*

"I take out the cube, and fill the tumbler with water. What is the shape of the water in the tumbler?" *The same shape as the tumbler.*

* Kinder-garten cube, for instance.

"Now I pour some of the water into this wine-glass. What shape has it now?" *The shape of the glass.*

"Now I fill this small bottle. What shape has the water now?" *The shape of the bottle.*

"The second fact I want you to remember about solids and liquids is this: *That solids have shapes of their own; but that liquids have no shapes of their own, and therefore they take the shapes of the vessels in which they are placed.*"

Metals and stones, desks and forms, houses and trees, books and pencils, all have *shapes* of their own, and we can only alter their shapes by cutting, or hammering, or pulling, or squeezing. Water, and other liquids, have no shapes of their own; the moment we remove the vessel which holds them they break up into numberless drops.

IV. To show that the particles of some solids are held more firmly together than those of other solids.

Call upon one child to try and break off a piece of iron with the fingers, then with a hammer. A second may take a flint, or a piece of brick. A third a piece of loaf sugar. A fourth may break a piece of chalk with the fingers, and a fifth a piece of table-salt.

"What do we learn from these experiments?" *That the tiny grains or bits are held together more firmly in some solids than in others.*

LESSON II.

"PROPERTIES" OF BODIES.

ARTICLES for illustration: orange, onion, sugar, salt, glass, sponge, water.

I. The distinguishing marks of bodies are called their "properties."

Teacher, showing an orange, asks:—"What is this?

How do you know it is an orange?" *By its shape. By its colour. By its size.* "What shape is it? What colour has it?"

"Here is an onion. How can we tell oranges from onions without looking at them?" *By their smell.*

"Here is a book and here a sheet of glass. What can we say about the glass which we cannot say of the book?" *We can see through the glass; but we cannot see through the book.*

"I daresay you remember what we say of glass because we can see through it?" *Glass is transparent.*

We can tell an orange by its *colour* and *shape* and *scent;* we know an onion by its strong *smell;* we can tell glass because we can *see through* it; we know sugar by its *sweet* taste, and salt by its *salt* taste.

There is something about almost everything in the world which helps us to tell *or distinguish* it from everything else. The *taste* of sugar, the *smell* of an onion, the *shape* of an egg, the *colour* of an orange, the *transparency* of glass, the *softness* of sponge, the *lightness* of cork, are all *marks* which help us to point out or distinguish these things one from another, and from other objects in the world. And what I want you to learn in this lesson is that to these *special marks* we give the name of PROPERTIES.

II. Bodies possess many properties.

Exp. 7. "Here is a piece of dry sponge. Squeeze it." *It feels soft.* "Put it on the water." *It is light. It sucks up water.* "Look at it." *It is full of little holes.*

"The sponge has many properties. Name some of them."

Exp. 8. "Take this piece of glass. Squeeze it." *It is hard.* "Hammer it." *It breaks easily.* "Pass the tips of your fingers across it." *It feels smooth.* "Place a book behind it." *We can see the book through the glass.*

"Glass has many properties. Name some of them."

III. Bodies may have some properties alike, or in common.

Exp. 9. "I take this lump of sugar and this lump of salt, and set them in a little coloured water on this plate. What do you see?" *The sugar and the salt suck up the water.*

"I put the sugar in this glass of water and the salt in another. What happens?" *Both* DISSOLVE *in the water.*

"Now you can name for me two properties which belong to sugar, and also to salt." *Both* SUCK UP *water; both* DISSOLVE *in water.*

"Taste the water in the glasses. Now you tell me in what respect sugar and salt are *unlike.*" *They are unlike in taste.*

"Name one property which the following pairs of bodies have in common."

1. Soda and ice. Both are *transparent.*
2. Cork and sponge. Both are *light.*
3. Lead and gold. Both are *heavy.*
4. Wool and sponge. Both are *soft* to the touch.
5. Ripe orange and sugar. Both are *sweet* to the taste.
6. Lemon and rhubarb. Both are *sour* to the taste.

LESSON III.

WEIGHT.

ARTICLES for illustration: pieces of metals, woods, cork, and sponge.

I. Weight is pressure downwards.

Exp. 10. Direct some of the scholars to hold in their hands any heavy substances within convenient reach. What can they say about them? They are *heavy.*

Next take lighter bodies, such as light wood, bark, cork, &c. What can be said of these bodies? They are *light.*

Exp. **11.** Place these bodies in a vessel of water; some float, some fall to the bottom. Distinguish again the *light* and *heavy* bodies. When placed in water in what direction do bodies press? *Downwards.*

Exp. 12. Place a heavy weight on some soft yielding substance such as putty, clay, snow, or sponge. In what direction does the weight press? *Downwards.*

Exp. 13. Direct a boy to place his right arm and hand in a horizontal position. Place weights—books for instance—on the hand until it is visible to the class that the hand is *pressed downwards.*

We call this pressure downwards WEIGHT. Weight is a property common to all bodies.

II. Actual weight depends partly on size.

"Wood floats on the water, iron sinks to the bottom. Which is the heavier body?" *Iron.*

"Here is a small piece of iron, and here a large block of wood. Which is the heavier?" *The wood.*

"What do we mean, then, when we say that iron is heavier than wood?" *We mean that when we take pieces of iron and wood of the* SAME SIZE, *the iron is heavier than the wood.*

When we compare the weights of bodies it is always understood that we are speaking of pieces of the *same size.*

III. The meaning of heavy and light.

"Here is a small block of wood. Has it any weight? Does it press down? Now take this small block of lead of the same size. Which presses down the harder? Which

has the greater weight? Compare the weight of the lead and the wood." *The lead is* HEAVY, *the wood is* LIGHT.

"What do we mean when we say that wood is light?" *We mean it has* LITTLE WEIGHT.

"And what do we mean when we say the lead is heavy?" *We mean that lead has* MUCH WEIGHT.

All bodies, then, have weight; and when we say that bodies such as wool, feathers, cork, and sponge are light, we mean that they possess but little weight, compared with such bodies as stones and metals.

IV. The uses we make of bodies as dependent on their weight.

The teacher will illustrate how heavy substances are used for weights, &c.; and light substances, as cork, for instance, for making life-buoys, cork jackets, &c.

*** As these lessons have a natural sequence, the introduction of any one lesson should, as a rule, be a recapitulation of the salient points in the preceding lesson.

LESSON IV.

POROUS. ABSORBENT.

ARTICLES for illustration: sponge, bread, piece of cane, sugar, salt, chalk, water, a couple of plates, and a couple of tumblers.

I. Meaning of porous.

Porous bodies absorb water. Select substances in which the pores can be readily seen—such as sponge, crumbs of bread, and a piece of cane—to show the meaning of porous. Let the children handle and examine the specimens, and discover the holes for themselves.

Exp. 14. Pour a little coloured water into a plate, and

in it place the sponge and the bread. The children will see the water gradually rising.

"Where does the water go?" *It fills up the tiny holes.*

"I place a piece of flint and a piece of lead in the water. Do these substances suck up the water?" *No.*

"Why not?" *They have no little holes.**

Exp. 15. Place the piece of cane, together with a slate pencil, in a bottle half filled with spirits of turpentine. In a few minutes the turpentine will have ascended through the pores to the top of the cane, and on the application of a lighted taper will burn with a smoky flame. The turpentine does not ascend through the slate pencil. Why not?

Exp. 16. Next let the children examine pieces of chalk, loaf sugar, table-salt, &c. Can they see any pores? No, but they are there. Show this by placing the chalk, &c., in the coloured water. The water is absorbed, we can see it rising; hence the pores must be there. *They are too small to be seen.*

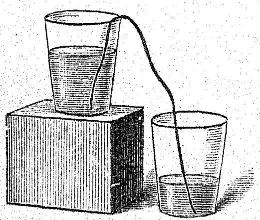
Fig. 1.

Exp. 17. Take a piece of loose twine, and, after immersing it in water place one end in a glass of water, and the other end in an empty glass placed at a lower elevation (Fig. 1).

After a time it will be found that all the water has been transferred to the lower glass. How has this been brought about? *The twine is porous; the water ascended through the pores to the top of the glass, just as it went up the cane; and then trickled down through the pores into the lower glass.*

* Note.—All substances are more or less absorbent. It will be sufficient, however, at this stage that the children should distinguish between substances manifestly absorbent, and those which absorb so very little as to be practically *non-absorbent*.

II The uses to which we put some porous bodies.

1. From this last experiment the children can be led to see why we make candles with wicks in the centre; also the use of wicks in oil-lamps.

2. Most articles of clothing are porous. Show the use of the "house-flannel."

3. Blotting-paper is *absorbent.* Write upon it. The ink spreads about—runs into the pores. How is blotting-paper useful?

"Writing-paper" is not porous, the pores have been filled up with *size.*

The teacher will doubtless have other substances at hand still further to illustrate the fact that porous bodies absorb water.

LESSON V.

POROUS BODIES. FILTERS.

ARTICLES for illustration: a small flower-pot, sponge, charcoal, sand, flour, blotting-paper, and a small funnel.

I. A sponge filter.

Exp. 18. Take a small common flower-pot—clean of course. Put a piece of sponge at the bottom. Pour in a little dirty water. When the pores in the sponge become filled with the water, the latter passes slowly through, but is not cleansed.

"Why?" *The pores are too large to prevent the tiny particles of mud from passing through.*

Put sawdust or sand with the water. These substances do not pass through.

"Why?" *The pores are too small to allow the particles of sawdust or sand to pass through.*

II. The charcoal filter.

Exp. 19. Show that charcoal is porous by standing a piece in water on a plate, as shown in the previous lesson.

Exp. 20. Place layers of powdered charcoal and sand on the sponge in the flower-pot. Pour in water; this, as it slowly trickles out at the bottom, will be found at first to be coloured with very fine particles of charcoal, but presently the drops will be clear and colourless.

Prepare a mixture of flour and water—half a tea-spoonful of flour well stirred into a tumbler of water. The mixture when poured into the filter will have a milky appearance, but the water will trickle out clear and bright.

III. Blotting-paper filter.

Exp. 21. Cut circles of blotting-paper say $3\frac{1}{2}$ or 4 inches in diameter. Take two thicknesses and fold twice, as in the cut (Fig. 2). Then open out to form a cone.

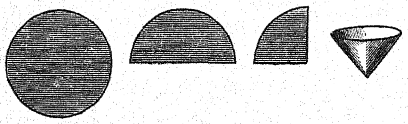

Fig. 2.

The filter will have the paper two thicknesses on one side, and six on the other side.

Place the cone in a small funnel and pour in the flour-mixture.

Clear water passes through, but the flour is left behind in the filter. The pores in the blotting-paper are too small to allow the flour-dust to pass through.

IV. The earth-filter.

Have you ever seen a spring? The water comes out of the ground clear and bright. Where did the spring get its water? *From the clouds.* The rain fell on the soil and became muddy and dirty; but it trickled slowly through the soil and the sand, and gravel, and rocks, and, as it comes out,

we see it quite clean again. How is this? The earth through which it has passed has acted as a *huge filter.*

V. Uses of filters.

To drink dirty water makes people ill. We can cleanse the water by filtering it. Spring water is best to drink, because it is clean, it has been filtered. When water is supplied to us through pipes, and we have to keep it in cisterns, it is best to filter the water before we drink it, because the pipes may not be clean, and dust and dirt may be present in the cistern.

LESSON VI.

NON-ABSORBENTS.

ARTICLES for illustration: any non-absorbent substances, as metals, glass, leather, clay, putty, &c.

I. Some non-absorbent bodies.

Show by experiment that many substances, such as glass, india-rubber, leather, metals, horn, ivory, &c., do not absorb water.

II. Non-absorbent substances do not allow water to pass through.

Refer to glass, earthenware, and china vessels, which we use for holding water and other liquids.

III. Uses to which some other non-absorbent substances ar put.

India-rubber for making waterproof clothing.

Leather for boots and shoes. Refer to the necessity for

keeping the feet dry. Bottles and drinking vessels were formerly made of leather.

Paint and *tar* are put on wood to prevent absorption of water, and consequent decay of the wood.

Dry wood absorbs water and swells. Window frames not painted would not fit closely. They would be too large in damp weather, or too small in dry weather.

Putty is used in glazing to prevent water passing through between the wood and the glass.

LESSON VII.

SOLUBLE.

ARTICLES for illustration: soluble and insoluble substances; sugar, alum, salt, soda—camphor, chalk, marble, wood.

I. The meaning of soluble.

Exp. 22. Put a teaspoonful of salt into a medium-sized test-tube three-parts filled with water. Stir, or shake; in a short time the salt has disappeared, and the water is just as clear as it was at first. Where is the salt? Clearly it is in the water. We can taste it, but not see it. It is *invisible.*

Repeat Exp. 6, p. 4. The oil is split up into such tiny drops that we cannot see them separately.

In the same way the salt splits into such tiny particles that, although we can taste them, we can neither see nor feel them.

Exp. 23. We can recover the salt from the water. Boil a little brine in the evaporating dish until the water has all been converted to steam. The salt is left behind.*

* Another and a pretty experiment to show that water may contain solids in solution, although we cannot see them. To the solution of salt add a few drops of nitrate of silver. A dense white curdy-looking solid is seen floating about. Add a little ammonia solution and the solid is again dissolved.

II. Some substances are soluble in water, and others insoluble.

Exp. 24. Show the solubility of sugar, alum, soda, salt, &c. Use glass vessels for clearer illustration.

Then the insolubility of other bodies, such as stone, chalk, coal, and wood, may be demonstrated.

Ask the children to name some of the things they know which dissolve in water, and others which do not so dissolve. Arrange the names in two columns on the blackboard.

III. Manufacture of salt and sugar.

The teacher may illustrate the use made of the solubility of substances by showing how salt is prepared from the water of brine springs and from sea water by evaporation; and also how sugar is prepared from the juice of the sugar-cane in a somewhat similar manner.*

LESSON VIII.

SOLVENTS—WATER, ALCOHOL, &c.

ARTICLES for illustration: small quantity of alum, saltpetre, lime, camphor, spirits of wine, benzine, and naphtha.

I. Water can dissolve only a certain quantity of a solid.

Exp. 25. Show this by putting more salt or sugar in a test-tube of water than the water can dissolve.

[Hasten the solution by boiling in the flame of the spirit-lamp.]

II. Some substances dissolve best in hot water, others in cold water.

Exp. 26. Make a hot saturated solution of alum, and set

* The manufacture of salt and sugar may form subjects for separate lessons.

it aside to cool. A large proportion of the alum assumes the solid form.* Why?

Exp. 27. Pour upon a clean piece of window-glass a hot saturated solution of saltpetre. Allow the liquid to drain off, hold it up to the sunlight, and beautiful crystals will be seen to spread over the glass. Why?

Tell the children that salt dissolves equally well in hot or cold water; but that lime dissolves best in cold water.

III. Water dissolves more of some substances than of others.

Exp. 28. Compare the solubility of salt and lime for instance, by trying to dissolve equal quantities in equal volumes of water.

Lime appears to be almost insoluble.

Exp. 29. Show that *some* lime is dissolved, by filtering the solution through blotting-paper (see p. 12) and then sending the breath into the clear solution through a glass tube. The water becomes milky, showing that there was something in the water which is not found in ordinary water. This must be lime, for nothing else was put in.

IV. Other solvents.

1. Alcohol, or spirits of wine.

Camphor dissolves in spirits of wine; but only to a very slight extent in water.

Exp. 30. Pour water into a solution of camphor, and the camphor becomes a feathery looking solid in the mixture.

2. Benzine.

Fat dissolves in benzine. Hence we use benzine to remove grease-spots from clothing. Show this by experiment.

* Take some small article made of wire, such as a basket, cover the wire with worsted, place the basket in a hot saturated solution of alum, and leave to cool slowly without disturbance. In a few days a pretty crystal basket will be seen

3. Naphtha.

India-rubber dissolves in naphtha. The solution can be spread over articles of clothing to make them waterproof.

LESSON IX.

ADHESIVE.

ARTICLES for illustration: any of the common well-known adhesive substances—Plaster of Paris, or cement, putty, and glue, also slaked lime, and sand.

I. Meaning of adhesive.

Exp. 31. Take any of the well-known sticky substances such as gum, sealing-wax, white of egg, paste, treacle, &c., and show by actual experiment how they *stick* things together. Such substances are said to be *sticky*, or *adhesive*.

Exp 32. A piece of gold-leaf *adheres* to the finger and is not easily removed.

Exp. 33. Plunge the finger into water; some of the water adheres to the finger. It is easily wiped off, because but little adhesive. Glue is not easily removed from the finger. Why? *Glue is more adhesive than water.*

Exp. 34. Plunge the finger into mercury. None of the mercury adheres. Why? *Mercury is not adhesive to the finger.*

Show how any of the above substances are useful because of their adhesive properties.

II. Some adhesive substances used in building.

1. Plaster of Paris.

Exp. 35. Take two pieces of marble or slate, or a couple of

bricks. Place in water. Mix a little plaster of Paris with water till it has about the consistency of thick cream. Remove the marble, slate, or bricks from the water, spread the plaster of Paris thickly over one piece, and press the other firmly over it. In a few minutes the plaster of Paris will become hard, and the solid substances are bound firmly together.

2. Cement.

Exp. 36. Cement such as is employed in making concrete foundations for walls, &c., may be used in the same way as plaster of Paris. For this illustration the cement should be mixed with about twice its volume of fine sharp sand.

3. Mortar.

Exp. 37. Show how mortar is made. [Ordinary mortar consists of slaked lime and sharp sand well mixed with water.] Illustrate the use of mortar. If possible show old mortar.

4. The uses of putty* and glue may also be illustrated.

LESSON X.

HARD AND SOFT.

ARTICLES for illustration : as many as possible of the following :—glass flint, steel, coins of various sorts, iron nail, tin, pewter, lead, chalk, rock-salt, wood, cork.

I. How one solid is shown to be harder than another.

The children may be called upon first roughly to distinguish between the *hard* and *soft* substances on the table by *feeling* them. The articles should be arranged in two divisions,

* Putty is composed of whiting and linseed oil, mixed and well worked together.

and their names written in two columns on the black-board.

Secondly, they should again separate the articles into three divisions by *scratching.*

Exp. 38. Try with the finger-nail.

Chalk, rock-salt, lead, wood, &c., can be scratched.

Set these on one side as forming the *1st division.*

Exp. 39. Try the remainder with the point of an iron nail. It will scratch gold, silver, copper, pewter, &c.

These will form the *2nd division.*

Exp. 40. Those which the iron nail will not scratch, viz. flint, glass, steel, &c.

These will form the *3rd division,* including the hardest substances.

Lastly, show the class that we can tell the harder of two bodies by rubbing them together. The harder will cut, or scratch the softer.

Exp. 41. Try iron with copper, brass with copper, iron with glass, and so on.

Tell the children that of all known bodies the diamond is the hardest. It will cut or scratch every other known substance. Instance the glazier cutting glass for windows.

Describe the diamond as looking like beautiful clear glass. Why so tiny a bit in the glazier's tool?

If a glass-cutter can be borrowed for the occasion, and its use shown, so much the better.

II. How some metals are made harder.

1. If steel be made red hot, and then cooled quickly by plunging into cold water, it becomes much harder.

2. Pure gold is almost as soft as lead, and if used for coins would soon wear away; a little copper mixed with it makes it much harder, and it does not wear away so quickly. Silver is hardened in the same way. Copper is also hardened

by mixing with it a little tin and zinc—two other metals. The mixture is called bronze, and pennies, halfpennies, and farthings are made of it.

LESSON XI.

BRITTLE, TOUGH, FLEXIBLE.

ARTICLES for illustration: pin, needle, various wires, old "kid" glove, chalk, and glass.

I. Meaning of brittle, tough, and flexible.

Exp. 42. Take a pin; ask a child to break it. It bends, but does not break. Try a needle; it bends and then breaks. In the same way try a piece of lead wire, or copper wire; and a piece of chalk, or slate pencil. The lead wire and the copper wire bend, but do not break. The chalk and the slate pencil break easily.

Exp. 43. Test by striking each article with a hammer. The same result: the pin and the lead and copper wires bend, but do not break; the needle, chalk, and slate pencil break into pieces.

Tell the class that when we can *break* articles into sharp pieces with the fingers, or by throwing them on the floor, or by striking with a hammer, we say they are *brittle*. When they *bend*, but do not break, we say they are *flexible*.

Exp. 44. Next compare lead wire with copper wire by bending backwards and forwards. The lead wire breaks easily, the copper does not. We say the copper wire is *tough*.

Exp. 45. Next try to tear a piece of thin leather—an old "kid" glove for instance—and then a piece of brown

paper. The paper is easily torn, the leather is not easily torn. Both the paper and the leather are flexible; but the leather is *tough* also, it is not easily torn.

II. Bodies which are brittle, &c.

By similar experiments the children may be led to see that such substances as

1. flint, china, glass, cast iron	are hard and brittle.
2. chalk, salt, bread	are soft and brittle.
3. copper, wrought iron, brass, hard wood	are hard and tough.
4. cork, sponge, india-rubber	are soft and tough.

LESSON XII.

ELASTIC.

ARTICLES for illustration: balls of wool, india-rubber, clay or putty, an orange, a piece of sponge, strip of glass, cork, and piece of "elastic."

I. Meaning of elastic.

Exp. 46. Take balls of wool, india-rubber, and clay or putty, an orange, and a piece of sponge. Let individual

scholars be called in front of the class to try the effect of squeezing each.

The orange, the wool and india-rubber balls, and the sponge take their own shapes again when the pressure is removed. They are said to be *elastic*. Clay, and putty, and butter are not elastic. Why?

Exp. 47. "Pull india-rubber, woollen cloth, or flannel. What is the result?" *These substances stretch or become longer.* "Let go with one hand. What follows?" *They go back again to the length they had before being stretched.* Try a band of india-rubber by actual measurement.

Why do we say that india-rubber, woollen cloth, flannel and such like articles are *elastic?*

Exp. 48. Take a flat ruler, a cane, or a piece of whalebone. Bend them and then let go with one hand. What is the result? *They spring back again.* These bodies also are *elastic.* Why do we say so?

Call the attention of the scholars to the three kinds of elasticity here illustrated, and give other examples of each kind.

II. Some bodies are more elastic than others.

Exp. 49. Test an ordinary wooden penholder, a quill pen, a strip of glass, and a slate pencil. The quill pen can be bent almost double before it breaks, the glass bends a little then snaps, and so of the wood; the slate pencil bends scarcely at all before it breaks.

In the same way compare other substances, such as—cork with sponge, leather with flannel, a book cover with a sheet of paper, and so on.

III. Uses we make of elastic substances.

1. *Cork for stopping bottles.* Show how the cork is compressed on passing through the narrower part of the neck of

the bottle, and how it opens out and fills the larger part of the neck.

2. *India-rubber for bands, "elastic,"* &c. [Cold has a curious effect on india-rubber: it makes the rubber non-elastic. Advantage is taken of this in the manufacture of "elastic." India-rubber threads are stretched, wound on rollers, and kept in the cold for a few days. They are then woven with the woollen, cotton, or silk threads into bands. The bands are passed over a hot roller and the rubber becomes elastic again.]

3. *Sponge for washing purposes.* We are able to squeeze out the dirty water. The sponge expands again and is ready to take up more water.

LESSON XIII.

PLASTIC.

ARTICLES for illustration: well-kneaded clay, and one or two moulds.

I. Meaning of plastic.

Exp. 50. Take a lump of clay [previously well kneaded], and having sprinkled over it a little fine sand press it into a mug, or cup, or "mould" of any form. Press well in in order that the clay may take the exact form of the inside of the vessel in which placed. Break the mould, or if of shape to allow it, turn out the "cast." [Plaster of Paris may be used in the place of clay.]

Fig. 3.

We have made the clay into a certain shape, the shape of

the vessel into which it was pressed. We call the vessel a *mould*, and because the clay can be formed or moulded, we say it is *plastic*. Plastic *means capable of being moulded, or formed into shape*.

Clay can be moulded into shape by the hand. Show this.

II. Things made in moulds from clay.

Exp. 51. Bricks. Show how bricks are made. A common slate pencil box with the bottom removed will serve as a mould.

Drain-pipes, tiles, &c., made in moulds from clay.

Explain that these things are baked to make them hard. *Contrast* the bricks before and after baking, with regard to properties. Before baking, *soft*, *plastic*, and *non-porous*; after baking, *hard*, *brittle*, and *porous*.

III. Things made from clay by the hand—earthenware and china.

Make a rough tea-cup to show the process. Stick on a handle.

Describe the manufacture of earthenware. A fine kind of clay, and burnt flints ground to powder, are well mixed. A tough paste is thus made, and from this the articles are formed. The articles are now baked in an oven. Next they are dipped in a mixture and baked again. The second baking produces the glaze, and renders the articles non-porous. Colours are next put on, and the articles again baked.

Ornaments, vases, figures, &c., are made of potters' clay mixed with fine sand, and then baked. These are called *terra cotta*, which means *baked earth*.

When warmed, gutta-percha is plastic; ornaments, soles for boots, &c., are made from it.

LESSON XIV.

FUSIBLE.

ARTICLES for illustration : lead, tin, cast articles, salt, and sugar

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I. Meaning of fusion.

Exp. 52. Melt lead in an iron spoon. Pour it out.

"It flows in drops. In what state is it?" *In a liquid state.*

"In what state was it before melting?" *In the solid state.*

"Then what change have we brought about by heating?" *We have changed the lead from the solid to the liquid state.*

Things which can be changed from the solid to the liquid state by heating are said to be *fusible.*

Ice is fusible. It does not change to water on a very cold day, except we bring it into a warm room, or hold it in the warm hand. It does not require much heat to *melt* or *fuse* it.

II. Common substances which are fusible.*

1. The *metals.* Some require very great heat. Melt a little tin; the iron spoon does not melt. Why? Show articles made of cast or fused iron—nails, hinges, grates, &c. Show any articles cast from bronze or bell-metal.

2. *Salt* is fusible at a great heat. Makes a glaze for some kinds of drain-pipes.

3. *Sugar.* Melt a little in the evaporating dish, and compare the fused sugar with the original.

4. A mixture of *flints* and *soda* is fusible; and when fused it makes a beautiful transparent glass.

* Of course, in strictness the term is used comparatively. Some substances are more fusible than others; and it is only to the former, those which are evidently fusible, that the term is here applied. With sufficient heat all solids are fusible. But those which are combustible "take fire" before reaching the point of fusion, unless totally excluded from the access of oxygen.

LESSON XV.

ON SOME FURTHER PROPERTIES OF THE COMMON METALS.

ARTICLES for illustration: any specimens of malleable and ductile metals, various wires, a thin rod of glass.

I. Malleable.

Exp. 53. Take a piece of lead, place it on a block, and hammer it. What is the result? It is *flattened* or spread out.

A bit of copper wire may be treated in the same way.

Refer to the blacksmith heating iron to a white heat, and then hammering it into various shapes.

Most of the metals can be hammered out without breaking; but gold and silver can be hammered out into thin leaves finer than the finest tissue paper. Show gold and silver "leaf" and tin "foil," and plates of any other metals.

Substances which spread out without breaking when hammered might be said to be *hammerable.* And that is just what "malleable" means. It is formed from the Latin word (*malleus*) for a hammer. But there is a kind of hammer made of wood, used by carpenters, called a mallet (little hammer), and gold and silver are beaten out with wooden hammers or mallets; hence we say *malleable,* and not *hammerable,* but the two words have the same meaning.

The teacher should now show the many uses to which these metals are put because of this property of *malleability.*

II. Ductile.

Exp. 54. Take a thin glass rod. Hold it in a lamp or gas-flame until it is softened, then gently draw it out into a thin thread. Tell the children then the word *ductile* is used for *can be drawn out.* Solid glass is not ductile. Glass

softened by heat is very ductile. Most of the metals are ductile, some much more so than others. Gold and silver *wire* can be made as fine as the finest thread. Show steel, copper, lead, and zinc wires.

III. Tenacious.

Exp. 55. Direct some of the children to test the strength of some of the specimen wires by trying to break them. Glass wire snaps very easily. It can scarcely hold together. Lead and zinc wire break more easily than copper, and so on.

We say that lead holds together more firmly, or is more *tenacious*, than glass; and copper is more *tenacious* than lead. The tiny particles in some metals hold together more firmly than in others. Why cannot we make so fine a wire or so thin a leaf of lead as we can of gold or copper? The tiny particles of lead do not hold together so firmly as those of gold or silver. Lead is not so *tenacious*.

Direct the attention of the children to some of the more common uses of wire.*

NOTE.—Lessons on any of the more common solids may now be introduced. In a great measure they should serve as the medium for a recapitulation of the ideas developed in the previous lessons. The following lessons on lead and sulphur are given as examples.

LESSON XVI.

LEAD.

ARTICLES for illustration: lead in as many forms as may conveniently be procured, as pipe, sheet, foil, and wire; also galena.

I. Its properties.

(*a*) "I want Harry to come to the table, and take this

* The common uses of metals may form the subject for other lessons.

piece of pipe in his hand. Look at it. I think you can tell me of what it is made?" *It is made of lead.*

"What can you say about its weight?" *It is very heavy.*

(*b*) "Take this nail, and try to scratch it. Now take this knife and try to cut it. What else does this teach you about lead?" *It is a soft metal.*

(*c*) "John shall take this piece and hammer it on the block of wood. What happens?" *It spreads out, or flattens.*

"What do we say of lead because we can hammer it out?" *It is malleable.*

"Here is a piece of lead 'foil.' What does that teach us?" *That lead is malleable.*

(*d*) "Here is a piece of lead wire. What can we learn from this?" *That lead is ductile.*

(*e*) "Bend the wire. It bends easily. What do we learn from this?" *That lead is very pliable.*

"It does not go back again to its former shape. What does this teach us?" *That lead is not elastic.*

(*f*) "Bend it backwards and forwards two or three times. What happens?" *It breaks.*

"What does this teach us?" *That lead wire is not very strong. It is not tenacious.*

(*g*) "I melt this piece of lead in the iron spoon. What does this teach?" *That lead is easily melted.*

"What difference do you see between the freshly melted lead and the piece of lead before it was melted?" *The fresh piece is much brighter. It shines more.*

(*h*) "Lead pipes and sheet-lead plates on roofs of houses last for very many years. What does this teach us?" *That it does not wear away quickly.*

"Yes, and when a thing does not wear away quickly we say it is *durable.*"

"We have learnt a good many things about lead. Tell me what they are once again." *Lead is heavy, soft, malleable, ductile, pliable, fusible,* and *durable.*

II. Its uses.

We have now to find out how all these properties of lead make the metal useful for various purposes.

"Here is our piece of lead pipe. Now why is lead specially useful for making pipes?"

[The teacher should here trace the course of one of the gas-pipes in the room, and show how it has to be bent and turned. Cast-iron pipes would do for straight tubes, but they could not be bent. Wrought iron would be much dearer, and would not bend so easily as lead. Silver or copper would do for gas-pipes, but they are too dear. Silver would be better than lead for water-pipes, but would cost too much. Copper would not do, because it would rust, and the rust of copper is a poison.]

Lead is very useful for making pipes, because—

1. It is easily bent.
2. It is soft enough to be cut with a knife or saw.
3. It does not rust.
4. It does not allow gas or water to escape.
5. It is cheap and durable.

For similar reasons it is useful as sheet-lead for covering the roofs of houses or floors, for lining wooden cisterns for holding water, and so on.

III. Alloys of lead.

[Mixtures of metals are called alloys.]

Lead and zinc melted or fused together make a very *ductile* alloy.

Advantage is taken of this to make wire, which, besides being cheaper, is softer and more easily bent and twisted about than copper or iron wire. Useful in the garden for tying up trees and shrubs. Why better than twine?

When a little of another and very hard metal called *arsenic*

is fused with lead, the alloy is harder than pure lead. This alloy is used for making *shot.* [Test the hardness of common shot by hammering.]

When another metal, very much like arsenic, called *antimony,* is fused with lead, it produces an alloy—*type-metal*—used for making type for printing. [If possible, show specimens.]

Solder is a mixture of lead and tin. [If possible, show its use.]

Pewter is an alloy of tin and lead.

IV. Whence obtained.

Tell the children that we get lead from mines—not pure lead, but lead mixed up with other substances.

[Show any ores of lead. The more common one, viz. *galena,* from which lead is *smelted,* is very plentiful.]

The lead is melted out, and run into moulds.

LESSON XVII.

SULPHUR.

ARTICLES for illustration: roll sulphur, "flowers" of sulphur, an olive-oil flask, and the spirit-lamp.

I. Its properties.

The children will discover the more obvious properties of sulphur under the guidance of the teacher. It is of a pale *yellow* colour, *hard, brittle, inflammable, insoluble* in water, and heavier than water.

Exp. 56. To show that sulphur is *fusible.* Put powdered roll sulphur, or flowers of sulphur, in an ordinary olive-oil flask; heat gently over the spirit-lamp. The sulphur easily

changes into the liquid state, when it has the colour of amber. As the temperature rises it becomes darker in colour, and takes about the consistence of treacle. Pour into cold water, and the once hard and brittle yellow sulphur is now soft and tenacious, and much like india-rubber.

Let the children compare the properties of this changed substance with those of roll sulphur.

Exp. 57. Although sulphur is insoluble in water, it is soluble in alcohol, or spirits of wine, and some other liquids. The teacher will dissolve a little in alcohol, or in bisulphide of carbon.

It readily takes fire, and from this property follow its chief uses.

II. Its uses.

1. Lucifer matches.

The children will be interested in learning how their grandfathers and grandmothers managed to get a light before "matches" were invented. Describe the "flint and steel" and the tinder-box. Show how sparks were obtained by striking a piece of steel. Use the back of a knife on the sharp edge of a broken flint. Next, show how the light was obtained by using strips of paper, or splinters of wood, the ends of which had been dipped in melted sulphur.

Next followed the improved sulphur matches, and in many places they are still used. The splinters of wood were dipped in melted sulphur as before; but in addition just the ends were dipped in a mixture which, when it became dry, ignited on being rubbed on a rough surface. This did away with the flint and steel, and the tinder-box.

Now the best matches are made without sulphur. Why? We are glad to be rid of the sulphur because of its suffocating smell.

2. Gunpowder.

This is an intimate mixture of about 15 parts, by weight,

of nitre, 2 parts sulphur, and 3 of charcoal. These are well ground, then well mixed, and made into a paste with water. The paste is pressed into hard cakes, these are broken into grains, and then dried.

Exp. 58. The teacher may make a little of the paste, not too soft. It burns with a hissing noise, and throws off showers of sparks.

3. Sulphur is also used in bleaching straw and wool, &c.

Exp. 59. Show this property of bleaching by holding a flower in the fumes of burning sulphur for a few seconds, most of the colour disappears.

4. Occasionally used as a medicine. The children may have heard of "brimstone and treacle."

SECOND STAGE.

SECOND STAGE.

LESSON I.

WATER.—ITS PROPERTIES.

ARTICLES for illustration: a "pop-gun" or substitute, a piece of glass tubing, a piece of lead or wooden pipe, and a bottle and cork.

I. Water is a liquid. [See First Stage, Lesson I., page 3.]

We may say water is a liquid because—

1. *It may be made to flow in drops.* Show this by letting water drop from a sponge, or from a bottle.

2. *It cannot be grasped by the hand.* Why? Its particle do not hold together firmly enough.

3. *It cannot be made to form a heap.* Try it on a slate or plate. It spreads out, and seeks to find the lowest place.

4. *It has no shape of its own.* It takes the shape of the vessel in which it is placed.

II. Water is clear, colourless, transparent, tasteless, and odourless.

All these simple properties may be readily elicited from the children by directing them to use their senses of sight, taste, and smell.

III. Water cannot be squeezed into a smaller space.

Exp. 60. To show this the teacher will require a tube and piston of some kind. A child's "pop-gun" will answer

very well; or take a straight quill, and a slice of raw potato, with a little stick for a piston. Plug one end of the quill by pushing through the potato. Nearly fill the quill with water, and then plug the other end by pressing the potato on the quill till the latter cuts through. The plug may be forced out or broken, but the column of water cannot be made shorter. A piece of strong glass tubing,* with pellets of "tow"† instead of potato, and a piston rod made of hard wood shaped as in the cut (Fig. 4) will form a better instrument, and will be useful in future lessons.

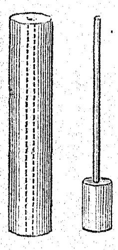

Fig. 4.

Exp. 61. Fill a bottle with water and try to force the cork in. Some of the water is squeezed out by the side of the cork as the cork is pressed in.

IV. Water presses sideways as well as downwards.

Children will appreciate the fact of the pressure downwards by trying to lift a bucket full of water.

Exp. 62. To show the pressure sideways take a piece of tube—any kind will answer; it may be cardboard, wood, or lead, provided we can readily pierce the walls. Plug one end of the tube firmly; make tiny holes in positions as shown in Fig. 5, and plug with wooden spikes. Fill with water, and remove the spikes.

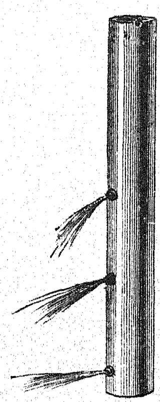

Fig. 5.

Direct the children to note carefully what follows.

Three tiny streams spout out. Are they alike? How do they differ? The top stream does not run out with so much force. The bottom stream seems to be in a greater hurry; it is pushed harder and so rushes out farther.

* Country boys make their pop-guns by forcing out the pith from a straight stick of elder-wood about an inch in diameter.

† Unravel a piece of old twine.

Note also that as the water in the tube lessens in volume the force of the streams lessens.

"What do we learn from this experiment?" Two things. (1) *That water presses sideways as well as downwards.* (2) *That the deeper the water the greater the pressure.*

Note.—Pressure in all directions is dealt with in a future lesson.

LESSON II.

WATER—A SOLVENT.

Articles for illustration: substances soluble in water, acetate of lead, liquid ammonia, tumbler, jug, and water.

I. Action of water on salt, sugar, alum, soda, &c.

Exp. 63. Show the *solvent* power of water by dissolving a little salt, sugar, alum, and soda in separate glasses or test-tubes.

How has the water changed the solid?

Can we see the salt or alum in the solution? The water has broken up the salt, &c., into such tiny particles that we cannot see them. It has made the solids *invisible.*

How do we know that the salt or sugar is everywhere in the water? Taste the smallest drop. It is salt or sweet as we dissolve the one solid or the other.

We should remember then that even the brightest and clearest liquid may contain some solid in solution although we cannot see it. Sometimes, indeed, we cannot discover the solid either by sight, taste, or smell.

Exp. 64. "Here is a liquid which contains a solid."

[Dissolve lead in white vinegar or acetic acid.] You cannot see it; but it is there as I shall show you.

Here is another liquid [liquid ammonia], but this contains

no solid. I pour a little of this into the first, and what do you see? A white solid shows itself, which slowly sinks to the bottom; the solid is painters' "white lead."

Exp. 65. "Here is another clear liquid [lime-water], of which you may drink. It is quite harmless; but it contains a solid in solution, which you cannot discover by sight, taste, smell. A boy shall blow through it by means of this glass tube. It gets milky-looking. By-and-by a white dust will fall to the bottom. This is chalk."

We can *recover* solids by evaporation. Show this by means of the evaporating dish.

Bodies which can be *broken up* or dissolved by liquids are said to be *soluble*, and the liquid which dissolves the solid is called the *solvent*. Water is therefore a *solvent* for salt, soda, &c.

II. Action of soluble bodies on liquids which dissolve them.

Exp. 66. Fill a tumbler full of water to the brim. Carefully pour it into an empty jug and add a couple of ounces of salt. A tumbler of water weighs about half a pound, so that the weight of the salt solution will be about ten ounces.

Now pour the solution into the tumbler. It is again *exactly full and no more.* Half a teaspoonful of water would have caused an overflow, but two ounces of salt have made no change in the size [volume] of the water.

What can we learn from this experiment? *That when we dissolve salt in water, the salt does not increase the bulk of the water.*

This is true also of other solids which dissolve in water. They do not increase the volume of the water. We may conclude from this that water is *porous,* although the pores are too small to be seen; and that the tiny particles of the solid fill up the pores.

If we add another ounce of salt to our solution we shall find

that the whole is not dissolved. A boy can eat only a certain quantity of bread at a time, and water can dissolve only a certain quantity of salt at a time, and no more. When the pores are full no more salt can be taken up.

Time permitting, the teacher may here show the different solvent power of water on different solids, and how heat affects this solvent power.

III. Uses of water dependent on its solvent power.

Pure water is obtained by boiling, and then changing the steam back to water [distillation].

Rain water and snow water are nearly pure; but river and spring water always hold solids in solution.

Where do these waters get their solids from?

When rain falls what becomes of it?

1. Part runs away in streams to the river and thence to the sea.

2. Part "dries up"—*evaporates* into the air.

3. Part soaks into the ground.

That which flows into rivers dissolves certain substances as it moves along, rubbing against the soil and sand and stones.

That which sinks into the ground dissolves a good deal more of rocks, &c., than river water. This water rushes out in springs. The best drinking water comes from springs.

Spring water contains solids. Instance the "fur" on the kettle.

Let the children taste distilled water. They will find it not agreeable; in fact, it will remind them of rain water, and they will learn that the best drinking water holds substances in solution. This occasion may be taken to show what are the impurities that make water bad for drinking, and what is the difference between mineral water and dirty water.

Refer to the fact that plants are dependent for much of their food on the solvent power of water.

LESSON III.

WATER AS VAPOUR. DEW.

ARTICLES for illustration: freshly cut leaves, flower in water, lump of ice.

I. Vapour, evaporation.

Suppose we hang out a wet cloth to dry. The cloth *dries*; but where does the water go to? You sprinkle a little water on the floor; it soon *dries up*. The roads may be watered; but they are soon dry again. What do we mean by *dries up?* Where does the water go?

You say it is gone away? I will tell you how it went away, and where it is gone.

You will remember how the water split up the salt into such tiny particles that we could not see them, and how even the tiniest drop of water got its share of the salt. Well, very much in the same way the air splits up the water into very fine particles, too small to be seen, and then the water mixes with the air, as the salt mixed with the water.

"I want you to remember that the water which is in the air, but which we cannot see, is called *vapour*; and that the change of water to vapour is called *evaporation*."

II. Other sources of vapour.

We see that the ground, and houses, and trees, and plants are all wet after a shower; and we see them dry very soon after, and we know that much of the water has become vapour; but there is water also going into the air in the form of vapour from leaves and from the bodies of animals.

Exp. 67. Place a few freshly cut leaves under a dry tumbler. The inside soon becomes covered with moisture. Why?

In the same way, if the naked arm be inserted in a jar, the

jar after a time will become covered with moisture, showing that, like the leaves, the skin gives off water.

Water also is always coming from the lungs. Breathe on cold slate or glass. What is the result?

The children will now be prepared to answer such questions as the following :—

"Why do flowers soon droop and wither after they are cut?"

"Why do we put flowers in water when we want to keep them fresh and bright?"

"Why does the water in the vessel decrease in quantity?"

"Why do we desire more to drink on a hot than on a cold day?"

"What do we mean when we say that 'ink dries?'"

III. How to collect vapour from the atmosphere.

Exp. 68. The teacher may show how to get vapour from the air, by bringing a glass of iced water into a warm room. The moisture soon covers the outside of the glass.*

In a similar way vapour from the air is settled at night on the cold grass and leaves. This is called *dew.*†

We often see moisture on the windows of a warm room, or on those of a closed carriage. Where does it come from? What causes it to settle on the window?

LESSON IV.

WATER AS FOG, MIST, CLOUD, RAIN, AND STEAM.

ARTICLES for illustration: apparatus for boiling water.

I. What is fog?

"What did we learn about vapour in our last lesson?" *It is in the air but we cannot see it.*

* The moisture is better seen perhaps on the outside of a silver vessel.

† A full explanation of the formation of dew is given in the Fourth Stage, Lesson XIII., page 145.

"What do we say of things which cannot be seen?" *They are invisible.*

"Can you tell me why vapour is invisible?" *Yes, the little particles when floating about in the air are too small to be seen.*

"In this lesson I am going to show you *how* this vapour changes back to water, and in what *forms* we see it in the air.

"But first of all I must tell you that when vapour changes back again to water we say the vapour *condenses.* To condense means to press into a smaller space, and so to thicken. Every one has heard of 'condensed milk.' The substance of the milk—the nourishing part—is pressed into a smaller space, and therefore thickened. Then it is said to be condensed. Just so when vapour falls back into a liquid state its particles are pressed together into smaller space. It is 'condensed.'

"You know that vapour condenses, because you have seen the water on the cold tumbler and on the window panes; but what causes the change?

"Breathe on this hot slate." No moisture.

"Breathe on the cold slate." We see the water.

"Breathe on this cold glass." We see the water.

"Where did the water come from that is on the slate?" *From the lungs.*

"Have you ever seen what looks something like smoke coming out of the mouth on a cold day?" *Yes.*

"That is the moisture of the breath condensed by the cold air."

"*It is the cold, then, which condenses vapour.*"

And I must tell you now that cold air makes the tiny particles of vapour join together—in companies, as we may say—to make tiny drops of water large enough for us to be able to see a mass of them together, and not large enough to be seen singly. The cold air changes the vapour into what we may call *water-dust.* This water-dust is *fog.*

On a foggy morning you may see a little white substance settled on the loose fibres of wool on your coat. Under a magnifying-glass we see that this is formed of rows of water-beads, so tiny that it would take fifty of them to make a drop the size of a pin's head. Then on spiders' webs you may see water-beads a little larger.

II. What are clouds?

The teacher may lead the children to answer this question for themselves by some such simple narrative as the following:—

"The morning was misty, but there was every prospect of a fine day, so we—that is, my brother and I—made up our minds to climb to the top of one of the high mountains we had seen a few miles off as we entered the village on the previous evening. Immediately after breakfast we trudged off, and soon arrived at the foot of the hill. So far we had walked in a thick mist; but, after climbing for about an hour, we walked, almost suddenly, out of the mist into the bright sunshine, and a glorious view burst upon us. Above were cloud-capped mountain-peaks; around, on every side, the lesser hills were bathed in a flood of sunlight; below, a great white sea of fog hid every house and tree. The mountain was steep, and we were glad now and then to take a rest, and to watch the fog as it slowly melted away. In another hour it had entirely disappeared, and we saw below us lesser hills and valleys, lakes, and streams, with villages dotted here and there, stretching for miles away.

"When we had reached within half a mile or so of the top of the peak we were climbing we entered another fog, very much like the one we had left in the valley in the morning, only this was colder and wetter. It was not pleasant, for we could see but a yard or two before us. However, we struggled on to the very top and rested awhile, hoping the fog would disperse. But we waited in vain, and were obliged

to descend without enjoying the splendid view we had promised ourselves from the top. We soon got back into the bright sunshine of the valley, but on looking behind us, there, on the top of the peak, resting like a nightcap, was the cloud through which we had passed."

III. Mist and rain.

"Where does the rain come from?" *It comes from the clouds.*

"How does the rain fall?" *It falls in drops.*

"Are the drops always of the same size?" *No; they are sometimes small, at other times large.*

"Do clouds always send down water?" *No.*

"How often can we see clouds?" *Almost always.*

"But it only rains now and then. How is this? I will tell you. When the clouds do not rain, the particles of water are all in small companies; but when the clouds get colder, then the particles gather into larger companies, so as to form drops. These drops fall, and we say it rains. When the drops are small we say it is a misty rain, or a 'Scotch mist.'"

IV. Steam.

Exp. 69. Show, by boiling water in a kettle or "Florence flask"* that the steam, as it issues from the spout or neck, is invisible.

It is commonly said that we see the steam as it issues from the steam-engine or the kettle, but this is not strictly true. As the steam spreads out in the air it gets a little cooled, and a *steam-fog* is formed. The steam-fog is what we see. *Steam-fog* is just like common fog, only it is hot.

Steam-fogs soon change to vapour, and then are, of course, invisible. Common fogs, too, evaporate; but more slowly than the steam-fog.

* Flasks made of *thin* glass in which olive-oil is imported. Being thin, they are less liable to crack.

[The fuller explanation of steam and its uses, and of the formation of rain, is given in the Fourth Stage, Lessons VIII. and XIV., pages 132 and 147.]

LESSON V.

WATER AS SNOW AND ICE.

Articles for illustration : water and a lump of ice. Snow if possible.

I. Snow, ice, and water compared.

Under the guidance of the teacher the children may first compare snow, ice, and water as to their chief properties. For example—

1. Water cannot be grasped by the hand ; snow may be pressed into hard balls.
2. Water and ice are alike clear and transparent.
3. Ice is lighter than water, and therefore rests near the top of the water.

II. Meaning of "frozen."

"When ice is taken into a warm room, what change takes place in it?" *It melts.*

"And what is it when melted?" *Water.*

"What do we call the change of ice to water?" *Melting.*

"If water is put in a very, very cold place, what change takes place?" *The water changes to ice.*

"And you know, I think, what we say when water is changed to ice?" *We say it is frozen.*

"Yes, and when we say that any substance which we usually see as a liquid is changed by cold to a solid we say it is *frozen.* Thus milk or quicksilver may be frozen. But when melted lead becomes solid again we do not say it is frozen. It is *solidified.* But frozen and solidified mean the same thing—*a change from the liquid to the solid*" state

III. What are snow, hail, and ice?

"Ice, you know, is solid water, but what are hail and snow?"

"Rain falls in drops—large and small. Sometimes rain-drops have to pass through very cold air in coming down. What happens?" *The drops freeze. The water becomes solid, and these little solid balls of ice we call hail.*

"But suppose the vapour as it condenses into fog and mist to become frozen and to fall, what then?" *We have a snowstorm.*

"There is much more to learn about snow, and hail, and ice; but all I want you to remember now is that *ice is solid water*, that *hail is solid rain*, and that *snow is solid fog and mist*."

IV. Uses of snow and ice.

The teacher may lastly call the attention of the children to the uses of snow and ice.

Although snow is so cold it is like a blanket in this, that it does not let warmth pass through it easily. Sheep are often buried in the snow, and are found to be much warmer than they would have been in the frosty air. Snow keeps the earth warm, and partly protects the plants from the frost.

Ice covers the water. It shuts off the cold air and so keeps the water beneath warmer for the benefit of the animals and plants which live in it.

LESSON VI

MERCURY, OR QUICKSILVER

Articles for illustration: mercury and tin-foil, and, if possible, scales for weighing, vermilion, and cinnabar—an ore of mercury.

I. Its properties.

The more evident properties—such as *its great weight*, *its*

state as a liquid, its easy divisibility into small drops, and its beautiful silvery lustre—may be elicited from the children.

Exp. 70. If the teacher has scales at hand he will compare the weight of mercury with the weight of water. A small cup, or small bottle of water weighs, say, half an ounce; the same volume of mercury will be found to weigh nearly fourteen half-ounces; that is, mercury is nearly fourteen times as heavy as water.

This metal is a liquid at ordinary temperatures, but in the very cold regions of the world it freezes in winter and becomes a solid metal like a bar of tin or lead. In this state it is malleable like most other metals. This the teacher can only tell the children, but he may *show* them that, like other liquids, it can be made to "boil" and change to invisible vapour.

Exp. 71. If the experiment be conducted in a test-tube, the vapour will condense again in tiny silvery drops on the cool glass near the open end of the tube.

II. Whence obtained.

Always obtained from mines. Sometimes found as pure liquid mercury in little hollows in rocks; more often as an *ore*. This ore consists of sulphur and mercury. The ore is roasted, the sulphur burns away, and the mercury becomes vapour. This vapour condenses in cool earthenware pipes as liquid mercury.

III. Uses.

1. For "silvering" looking-glasses.

A piece of tin-foil, of the same size as the glass to be "silvered," is spread on a perfectly flat and smooth stone. Mercury is poured on the tin-foil and made to cover it. The glass plate is then caused to slide gently over, not quite

touching the tin-foil. The glass thus sweeps off a large proportion of the mercury and all the air, leaving but a thin film of the liquid metal. Next the glass is heavily weighted. In a short time the mercury and the tin-foil form a solid *amalgam*, which adheres to the plate.

Exp. 72. The teacher can illustrate the formation of amalgams by working up a little tin-foil, such as is used for wrapping round tobacco, with mercury until the mixture has the consistency of putty.

2. For the extraction of silver and gold from their crushed ores.

The mercury forms an amalgam with these metals. To obtain the precious metals the mercury is driven off by heat. It is, however, collected to be used again for a similar purpose.

3. Mercury is also used for the preparation of a very bright red-coloured powder called *vermilion*. Vermilion is used as a paint, and for colouring *sealing-wax*. Other uses will appear in future lessons.

LESSON VII.

AIR—A SUBSTANCE, INVISIBLE, OCCUPIES SPACE, HAS WEIGHT.

ARTICLES for illustration: a tumbler and basin of water, test-tubes, and a little ammonia and hydrochloric acid.

I. Air—a substance, invisible, occupies space.

Hitherto we have dealt with things which we can see; now we propose to find out something about some bodies which we cannot see.

"I have here a tumbler. Is it full or empty?"

"Empty you say. I think not; I shall show you that it is full of something."

Exp. 73. See! I turn it bottom upwards, and press it down into this basin of water. "Does the water fill the glass? A boy shall come to the table and press it further down. Can he make the water quite fill the glass." *No.*

"Then there must be something in the glass. I lean it on one side, and out something comes in a great bubble. What was it." *Air.*

"Then what was there in the glass?" *Air.*

"What do you say about the air because you cannot see it?" *We say it is invisible.*

It is difficult for little children to appreciate the fact that bodies do exist although invisible, and the teacher should therefore multiply instances. He may refer to salt and sugar in solution, and to vapour and steam.

Exp. 74. A pretty experiment may be shown as a further illustration. Hold an inverted test-tube for a few moments over the mouth of the bottle containing *ammonid-water*, and another over a bottle containing *hydrochloric acid.* The tubes become filled with the gases that rise from the bottles, but nothing can be seen. Place the mouth of the first over the mouth of the second, and then invert. A white cloud appears in the tubes, which gradually falls as a white flaky solid to the bottom of the lower test-tube. Or, fill a bladder with air. Prick it. The children may *feel* and *hear* the air rushing out, although they cannot see it.

II. Air has weight.

That air has weight is readily shown by weighing a flask from which the air has been taken, and then weighing it again when the air has been allowed to enter; but as few teachers will be able to command the necessary apparatus, it

must suffice here to show by a diagram on the blackboard how the weight of air is ascertained (Fig. 6).

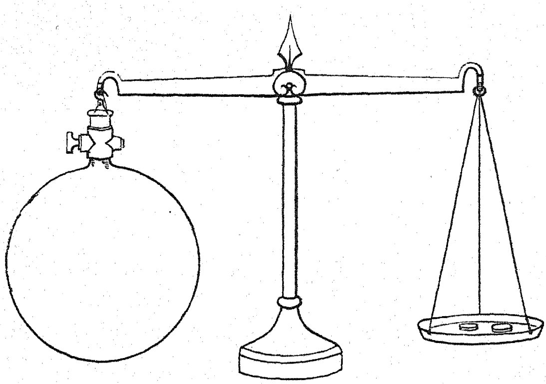

Fig. 6.

A box measuring a foot in each direction will hold about an ounce of air.

LESSON VIII.

AIR PRESSES IN ALL DIRECTIONS.

ARTICLES for illustration: tumbler, water in large basin, piece of thin card, a boy's sucker.

I. Pressure downwards.

Exp. 75. Fill a tumbler with water, invert it and, raise nearly out of the water (Fig. 7). The water does not fall out of the tumbler. Why not? There must be some pressure on the free surface of the water. And this can only be the air, for nothing else rests on the water.

Exp. 76. Repeat the same experiment, using a wide tube, securely corked, or covered with a piece of bladder at one end. Remove the cork or prick the bladder; the water

falls. Why? If the tube is not too wide, the thumb placed over one end will answer equally well.

The air presses *downwards* on the free surface of the

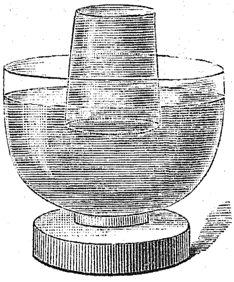

Fig. 7.

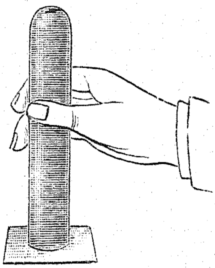

Fig. 8.

water with sufficient force to hold the water up in the tumbler or tube.

II. Pressure upwards.

Exp. 77. Fill a tumbler, wineglass, or wide test-tube to the brim with water. Press over its open end a stiff piece of paper or a card. Hold the card in its place and invert the glass; the water will not run out (Fig. 8). Why? It is because the air presses *upwards* on the paper, and keeps the water in.

III. Pressure sideways and in all directions.

Exp. 78. Cut a circle of about four inches in diameter from a piece of moderately thick leather. Soak till it is soft and flexible. Tie a knot at the end of a piece of string, and pass the other end through a small hole cut in the centre of the leather. Dip the leather in water, and then press it down on to a piece of slate or smooth stone. We can lift the slate or stone by means of the *sucker*, and the sucker adheres equally well, no matter in what position the slate or stone is placed.

Now, why do we press down the sucker, and how is it that

the leather holds on so firmly? Leather is not adhesive, neither will water stick the leather to a stone.

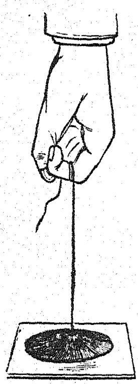
Fig. 9.

We press the leather to squeeze out all the air. We then raise the leather a little by pulling the string, and the pressure of the air on the leather on one side, and the slate or stone on the other, hold the two firmly together. It is just as though I held the leather with my left hand and the stone with the right, and pressed the two together.

You will learn more in a future lesson about the pressure of air. What I want you to remember now is that air presses in all directions, *downwards*, *upwards*, and *sideways*.

The teacher may refer to the manner in which limpets fasten themselves on the rocks when the tide recedes; and to the suckers on the feet of flies enabling them to walk on the ceiling body downwards.

LESSON IX.

AIR IS ELASTIC.

ARTICLES for illustration: sponge, pop-gun, or cylinder and air-tight piston, bladder, or any air-tight bag.

The teacher should introduce the subject of this lesson by referring to the elasticity of solids. Sponge may be taken as an example, because the elasticity of air is somewhat similar to the elasticity of sponge.

Like sponge, air can be pressed into a smaller space. It is *compressible*. And, like sponge, when the pressure is removed it opens out again. That is, air *is elastic*.

Exp. 79. The first property is easily shown by means of the pop-gun.

How does the pop-gun work? When the cork is placed in the end of the gun, the barrel is full of air. If the cork were not in, the air would all be pushed out by the rod. But the cork keeps the air in. As the rod is pressed in the air is pressed closer together, and occupies a smaller space. When the rod is pressed half way, the air occupies half the space it occupied before. Now when air is squeezed in this way, it tries to open a way out for itself, and as the rod is pressed in still farther, the air forces out the cork all at once, and so makes the popping sound. It is not the rod alone which forces out the cork, for it is not long enough to touch the cork. It is the air between the rod and the cork trying to expand to its former size which makes the latter fly out. In other words, it is due to the elasticity of the air.

The teacher may explain the action of the pop gun made out of a goose quill, as described in Lesson I., p. 36.

The different action of water and air in the pop-gun, should also be shown.

Exp. 80. A more perfect apparatus for showing the elasticity of the air is an air-tight brass tube with a closely fitting piston, as shown in Fig. 10.

When the piston is pressed down considerable resistance is felt, and if it is pressed down quickly and then released, it springs back again.

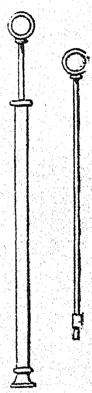

Fig. 10.

The teacher may further illustrate the elasticity of air by means of any suitable articles within reach, such as a bladder, or an air-tight india-rubber cushion filled with air. The bladder or bag may be pressed at will; but the air within always forces it into its original shape when the pressure is withdrawn.

LESSON X.

GAS.

Articles for illustration: sulphuric acid, a little sulphide of iron, bottles, and water.

I. What is a gas?

The teacher should call on the children to reproduce the ideas already acquired about solids and liquids.

A *solid* is a substance which retains its form and size, unless acted on with more or less force.

A *liquid* is a substance which keeps its own size, but takes up the shape of the vessel in which placed, and spreads itself out so as always to have a level surface.

We have now to consider some other substances which are neither solids nor liquids. We call them *gases*. Most of you know one gas—that which we burn to give us light. *Air* is one of these gases. What have we already learnt about air? It has *weight*, but is very light. It takes up room for itself, viz. *occupies space*. It is *compressible* and *elastic*.

All gases have *weight*, [but as we shall learn by-and-by, some are heavier than others,] and they all *occupy space*. Like air, too, they are all very *compressible* and very *elastic*.

There is one more fact to learn about gases, including air. They are always *trying to spread out more and more*, so that very little of a gas will fill a large space. We can half-fill a bottle with a liquid, but we cannot half-fill a bottle with a gas. The gas will spread out and *fill* the bottle.

A rough idea of the constant tendency of gases to *expand* may be shown by allowing a little coal gas to escape. It soon fills the room, as may be detected by its unpleasant smell.

Exp. 81. A better method is to fill a bottle* with some strong-smelling gas, such as sulphuretted hydrogen,† and allow it to escape into the room. It will soon be discovered in every part of the room.

We can now answer the question, "What is a gas?"

Gas is a substance which (unless confined) *retains neither form nor size, and which has no surface.*

II. How liquids and gases are alike.

Show how water may be made to *flow* in a stream.

Exp. 82. Then make a little carbonic acid gas by pouring very dilute sulphuric, or hydrochloric acid, on a few pieces of chalk, and show how this can be made to *flow* into another tumbler. We cannot see the gas flow out of one vessel into the other, but we can see its effect when poured

* As in future lessons we shall often have to fill bottles with gases, it will be well to show the method here. (1) When the gas is not soluble in water, take any vessel, such as a wooden bucket, and fix a shelf across it two or three inches from the top. Cut a hole in the shelf. Nearly fill the vessel with water. This forms a "pneumatic trough." Fill the bottle with water

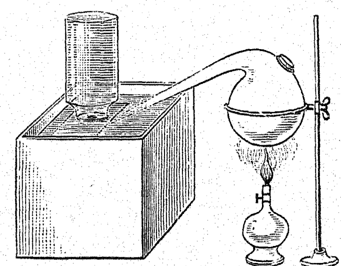

Fig. 11.

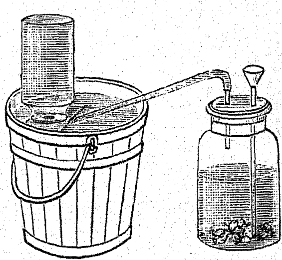

Fig. 12.

in the trough, and place it mouth downward on the shelf over the hole. The gas from the generating bottle passes along a tube, and bubbles up into the bottle through the hole in the shelf. (See Figs. 11 and 12.) (2) When the gas is soluble in water it must be collected by displacement of air. (See Fig. 67.) If the gas is lighter than air the jar must be inverted and the gas poured upwards.

† Sulphuretted hydrogen is formed in abundance when diluted sulphuric acid is poured on sulphide of iron—both inexpensive substances. For preparation (see Fig. 67). Heat is not required.

on a lighted taper. The flame is extinguished. Both liquids and gases may be made to *flow*; hence they are called *fluids*. The word *fluid* means *flowing*.

The teacher may conclude this lesson by showing how extremely useful in nature is the constant *expansion of gases*. Stagnant pools, heaps of refuse, decaying vegetable and animal matter, give of gases which to breathe in quantity would cause illness, and perhaps death. But they soon expand, and are lost to the senses in the vast atmosphere around and above us.

LESSON XI.

COAL-GAS.

ARTICLES for illustration: long clay pipe, small coal, clay, soda-water bottle, wire gauze.

I. Its properties.

Attach a piece of india-rubber tubing to a gas-burner and collect the gas in a bottle, as described in the foot-note, page 55.

Like air, coal-gas is *invisible;* but, unlike air, it has an *unpleasant smell*, and burns with a *bright flame*.

II. Its manufacture.

Exp. 83. Take a clay tobacco-pipe with large bowl and long stem. Fill the bowl nearly to the brim with crushed coal, and stop firmly with well-kneaded clay. Put the charged bowl into a clear fire, and direct the children to take note of the result. First steam pours out of the stem. This is from the moisture in the coal. When this has ceased, a stream of coal-gas follows, which may be ignited. It burns like a candle.

At the present stage it will be sufficient to let the children understand that coal-gas is manufactured on a large scale in a manner similar to that we have employed in making a tiny quantity. Great iron vessels, called *retorts*, are used instead of the bowl of the pipe, and long *iron tubes* instead of the stem.

III. Coal-gas in mines. Fire-damp.

Refer to what sometimes happens when coal-gas escapes into a room. It mixes with the air, some one brings in a light, and there is a sudden explosion; the windows are blown out, or the walls thrown down, and perhaps people are injured.

Exp. 84. Show *slight explosion* of a mixture of coal-gas and air in a soda-water bottle. Fill the bottle with water, admit air to fill about two-thirds of bottle, and then fill up with coal-gas [see note, page 55]. Apply a lighted taper to the mouth of the bottle.

"What happens in mines?"

"Firstly, the owners of a coal-mine get all the fresh air they can into the mine, or the men could not breathe, and would die.

"Secondly, gas often escapes in large quantities from the coal in the mine without any heat.

"Thirdly, it is dark, and the men must have lights to see to work."

"Here then we have everything wanted for a dreadful explosion. Fortunately when a light is placed in a lamp made of wire gauze it will not set fire to the mixture. But then sometimes the men are careless, and explosions happen, and many of the poor miners are killed."

Exp. 85. If a piece of wire gauze be held in a jet of gas, an inch or two above the "burner," the gas may be burned above the gauze without igniting the gas below.

IV. Useful lessons to be learnt.

1. Never sleep in a room into which coal-gas is escaping. It may poison you.

2. Whenever there is an escape of gas open the doors and windows. Gas *expands*, and soon mixes with the air outside.

3. Never take a light to see where the leakage is; the mixture of gas and air might explode and kill you.

LESSON XII.

TAR.

ARTICLES for illustration: tar, spirits of wine or ether, naphtha, and if convenient, carbolic acid, and any aniline colours.

I. Whence obtained.

Tar is one of the products formed during the manufacture of gas from coal. It comes over from the retort with the gas, and is collected in water through which the gas is made to pass.

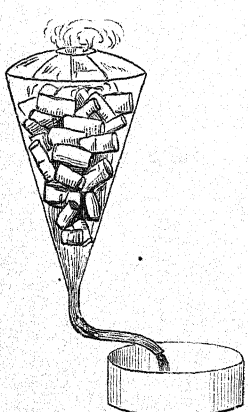

Fig. 13.

It may be made from wood in the same way. That is, the wood may be enclosed in an iron retort and heated just as we heat coal. In the one case *charcoal* is left behind, in the other *coke*.

The teacher should show these substances.

Planks used in ship-building are covered with wood-tar made from logs of pine-wood.

Wood-tar is obtained as follows:—a hollow or kiln is

made of sugar-loaf shape (see Fig. 13) in the side of a hill, having a small opening at the bottom which leads to a tank. The kiln is filled with logs of pine-wood and covered with turf, a hole being left in the top, where the fire is kindled. The wood smoulders, and becomes charred from the top downwards, while the tar oozes out at the bottom.

II. Properties.

Many of the properties of tar* may be elicited from the children by leading questions.

Wood-tar is of a *blackish-brown* colour.

Coal-tar is *black*, in each case a *viscous fluid*—viz. a fluid which is thick and sluggish—having the consistency of liquid glue, or treacle. *Unpleasant smell*, and *bitter burning taste*. *Burns* freely, giving off volumes of *heavy smoke*. A little *heavier than water*, and therefore sinks to the bottom when poured into water. Does not mix with water; and soap and water will not remove it from the fingers.

Dissolves partly in *alcohol*, and partly in *ether* and *spirits of turpentine*, and mixes freely with *oils* and *fats*.

To cleanse the hands of tar, rub with turpentine, or with a little oil or fat, and then wash with soap and water.

The most important property of tar is its power of preventing decay. Salt and sugar are used to preserve meat; but tar is a more powerful preservative than either. Tar is not used, however, for this purpose because of its unpleasant taste.

III. Its uses.

1. For preserving wood. Timber is sometimes steeped in tar. Sometimes the tar is spread over woodwork like paint.

2. *Naphtha*, useful for dissolving india-rubber; *carbolic acid*, used for disinfecting purposes and in the making of

* Tar is a mixture of many bodies. As these vary with the source whence the tar was derived, and the amount of heat used in distillation, its properties vary somewhat.

carbolic soap; *aniline colours,* used for dyeing calico, and cloth, and other important substances are got from tar.

How far the teacher will pursue this subject must depend on the capacity and intelligence of the scholars.

LESSON XIII.

CARBONIC ACID.

ARTICLES for illustration: bottles, tumblers, chalk or marble, and hydrochloric acid.

I. Its properties.

To show its properties collect one or two bottles of the gas. (See Fig. 12.)

Exp. 86. [Carbonic acid gas is readily obtained by pouring dilute hydrochloric acid on lumps of marble or chalk.]

The gas is *invisible* and *without smell.* It is also a *heavy* gas; it can be poured from one vessel to another. (See experiment Lesson X.)

Its most striking property can be shown by plunging a lighted taper into a jar or bottle of the gas. The flame is at once extinguished. Or a stream from a jet may be made to play on a burning match. The flame is extinguished. Not only does carbonic acid gas not burn itself, but it prevents other bodies from burning.

[A portable fire extinguisher has been constructed which makes carbonic acid gas, and pours it out through a tube.]

We breathe out carbonic acid gas from the lungs.

Exp. 87. Send a stream of carbonic acid gas into lime-water. The children will see that the gas makes the water look milky; they may be told that the water held lime in solution, and that the gas united with it and formed chalk, which is insoluble. Hence the white colour.

Now call on one of the scholars to breathe out through a solution of lime-water and note a result similar to the above. What conclusion can the children draw from the experiment? *We breathe out carbonic acid gas.*

It took a much longer time to make the water milky by breathing through it than by sending the gas from the bottle through it. Why? *Because the quantity we breathe out is very small indeed.*

Exp. 88. A saucer of lime-water left to stand for a few hours will become milky-looking on the surface. Why? *There is always a small amount of carbonic acid gas present in the air.*

II. Carbonic acid produced in burning.

We have seen in previous lessons that we breathe out vapour of water from the lungs, and that water is produced by flame. In this lesson we have learnt that we breathe out carbonic acid gas, and now you have to learn that flame also produces carbonic acid gas.

Exp. 89. Take a bottle with wide mouth—a large "pickle-bottle" will answer very well—invert it over a lighted candle (Fig. 14). When the candle is extinguished place the bottle over a wine glass of lime water (Fig. 15). In a few minutes we see the milky looking surface, showing that carbonic acid gas was present in the bottle. This gas was produced by the burning of the candle.

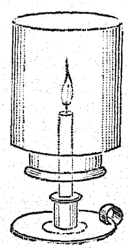
Fig. 14.

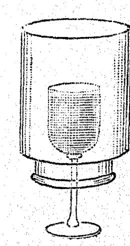
Fig. 15.

III. Carbonic acid gas is poisonous.

The teacher will refer (1) to the fact that chalk or limestone when heated in *kilns* gives off carbonic acid gas [draw the

outline of a lime-kiln on the blackboard], and that people who have gone into kilns, recently emptied, for the sake of the warmth, have gone to sleep, and never wakened again; (2) to the choke-damp (carbonic acid gas) formed by the explosion of fire-damp (coal-gas), which probably kills more miners than the explosion itself.

The amount of carbonic acid gas in the air is not sufficient in quantity to do us any harm; but if we shut ourselves up in a close room, and breathe the same air over and over again, the amount of the gas is increased, and we become heavy and sleepy, and perhaps get a headache.

IV. A useful lesson.

It is not healthy to live in a close room. Allow the foul air to escape, and the pure air to come in, by opening windows or doors. If opened ever so little the air is kept purer and more healthy than when closed.

LESSON XIV.

PARAFFIN OIL.

ARTICLES for illustration, benzoline, paraffin oil, paraffin candles, and, if possible, benzoline and paraffin lamps.

I. Properties.

The properties more easily discerned should be educed in the usual way. Paraffin oil is a *colourless liquid*, *lighter than water*, having an *unpleasant smell*.

The oil is not explosive as is often supposed, and as a liquid it does not burn.

Exp. 90. Pour a little into a cup, and plunge into it a lighted taper. There is no explosion, and the oil does not

burn; on the contrary, the taper will be extinguished, just as if it had been plunged into water.

Whence, then, do we obtain the beautiful light given by paraffin lamps? It is from the invisible *vapour* or *gas* into which the paraffin liquid changes when heated.

A mixture of the vapour from paraffin oil and air is explosive, just like a mixture of coal-gas and air; and it is the paraffin gas which burns just as coal-gas burns.

II. Whence obtained.

The children will remember how coal-gas was obtained from coal. A crude, viz. impure, oil is obtained from coal just in the same way, only the coal is not heated so much.

The poor kinds of coal are used for the purpose of extracting this oil. In America the oil is obtained from oil-wells. It is called *petroleum*, that is, rock-oil, and millions of gallons are brought to this country every year.

The crude oil is separated into benzoline, paraffin oil, and solid white paraffin.

III. Uses.

Benzoline is used for sponge lamps. A lamp should be shown, and the teachers should point out the danger in carelessly using benzoline. It gives off vapour in hot weather, and may thus form an explosive mixture with the air. It burns readily also on the application of a flame. Hence it should never be handled by candle-light. Benzoline is useful in removing grease-spots from clothing. It dissolves the grease. This should be illustrated.

Paraffin oil is used for burning in lamps. A lamp should be shown.

Paraffin, when purified, is a pure white solid. It is used for making candles.

LESSON XV.

CANDLES.

ARTICLES for illustration: as many kinds of candles as can be obtained, the stem of a tobacco-pipe.

I. Kinds of candles.

1. The *rushlight.* This is now seldom used, but it was the light by which our grandfathers and grandmothers had to read and sew. It was made of the *pith* of rushes dipped in fat.

2. The *common dip.* Dips are made like the rushlights; only instead of the rush-pith the wicks are made of loosely twisted cotton threads. The wicks are dipped in the melted tallow two, three, four or more times, but allowed to cool between each dipping. The cooling allows the tallow to set, and in the next dipping more tallow adheres.

3. *Mould candles.* What is a mould? Look at the candle. What is the shape of the mould? Where must the wick be placed. Why called mould-candles? The wick is plaited. Why? It saves snuffing. It causes the wick as it burns to curve slightly outwards, and the wick is completely consumed. [See Fifth Stage, Lesson VII., page 184.]

Paraffin, wax, oil obtained from the head of a whale, and many other fats and oils are used in the manufacture of candles.

II. How a candle burns.

The teacher should have a candle burning in front of the class, and call children to note first the solid fat, then the cup at the top and what is in it. What liquefies the hard fat? Next they should note the liquid fat going up the wick. Place a twist of cotton in water to show how the water ascends.

At the top of the wick the liquid is changed to a gas by the heat. Show this by inserting a small tube into the middle of the flame; the gas pours out at the other end and may be ignited. Compare with the paraffin oil going up the wick, and with turpentine up a piece of cane.

The teacher should draw the attention of the children to the fact that whether we use candles, or oil, or coal-gas to light our houses, we always burn *gas* of one kind or another.

LESSON XVI.

SOAP-BUBBLES AND WHAT THEY TEACH.

ARTICLES for illustration: tobacco-pipe, soap and hot water, a little oil, water, and quicksilver.

I. How made.

"To-day our lesson is to be on soap-bubbles and what they teach us. I must first of all show you how to make soap-bubbles, and then I dare say you will try and make them for yourselves."

Exp. 91. "You all know what this is?" *A tobacco-pipe.* "And this I dare say you can tell by its colour and smell?" *Soap.*

"Yes, and here I have water. I will heat a little in this test-tube over the spirit lamp."

"Now I shall dissolve some of the soap in the warm water. Next I warm the pipe and put a drop or two of the soap mixture in the bottom of the bowl."

"Now I blow gently. There it is. What do you see?" *A ball.*

"Yes, and we call this ball a *soap-bubble.* Look, I shake it off. There it goes. In what direction is it going?" *Upwards.*

"Ah, where is it now?" *It has burst.*

"I will make another. There it goes, up again."

"Watch it. In what direction is it going now?" *It is coming down.*

"We will find out something more about these pretty balls. I put a little water in the pipe and blow. I make bubbles, but they break at once in the bowl of the pipe. Why? I will tell you. The particles of water alone cannot stick together firmly enough to make the ball. The soap sticks them together, so that the thin covering of the soap-bubble is just *a very thin sheet of soap and water.*"

"But what is there inside the ball? Think for a moment. How did I make the soap bubble?" *By blowing through the stem of the pipe.*

"And what did I blow through the stem?" *Air.*

"Now breathe gently on your hands? How does the air which comes from the lungs feel?" *It feels warm.*

"Then what kind of air did I breathe into the bubble?" *Warm air.*

"Now you can tell of what the bubble is made? What is the covering?" *A sheet of soap and water.*

"And what is there inside?" *Warm air.*

II. What they teach.

"And now we have to ask the soap-bubble why it first went up, and then came down again."

"And first why does the bubble ascend?"

"Here is a test-tube, what is there in it?" *Nothing.*

"Oh yes, there is something in it although you see nothing. What fills it?" *Air.*

"Now I pour in a little oil. Where does the oil go?" *To the bottom of the tube.*

"And what has become of the air which was at the bottom where the oil now is? I will tell you, *the oil has pushed it up.*"

"Now I pour in a little water. Where do you see the water?" *At the bottom.*

"And where is the oil?" *Just above the water.*

"And how has the oil been raised higher up in the tube?" *The water has pushed it up.*

"Lastly, I pour in a little quicksilver. Where does that go?" *To the bottom.*

"And what has the quicksilver done to the oil and the water?" *It has pushed them higher up in the tube.*

"Now I will shake the test-tube. What do you see?" *The quicksilver is at the bottom, and the oil and water mixed up.*

"Wait a minute or two. Now what do you see?" *The oil is rising to the top of the water.*

"From these experiments you see that the heavier bodies always *press up* the lighter ones and take their places. And this is what I want you particularly to remember. *Neither light bodies nor heavy bodies ascend of themselves.* If they go up they are always *pushed up.*"

"On a cold day stand under an open window. What do you feel?" *The cold air coming down.*

"Yes, it comes down and takes the place of the warmer air of the room. But where does the warm air go? *It is pushed up to the top of the room, and squeezed out wherever there are openings.*"

"When the air of the room is warm open the door about an inch. Hold a lighted candle near the top; the flame is blown outwards. Hold it near the bottom; the flame is blown inwards. The cold air is coming in at the bottom and the warm air is going out at the top, and the cold air forces up the warmer air just as water forces up oil, or quicksilver forces up water. *Hence we know that the warm air is lighter than the colder air.*"

"We will now return to our soap-bubble. What kind of air had it inside?" *Warm air.*

"And which is the lighter, warm or cold air?" *Warm air.*

"Then why did the bubble ascend?" *The cold air pushed up the warmer, and therefore lighter air in the bubble.*

"Now we have to ask, Why did the soap bubble come down again? When you put hot water out in the cold does it remain hot?" *No, it soon gets cold.*

"And the warm air soon gets cool and heavier, and the soap-and-water-covering of the bubble helps to make it a little heavier still, and down it comes.

"I think you must have learnt in this lesson why bodies lighter than water ascend in water, and why bodies lighter than air ascend in air. You will learn in the next lesson about other bodies which are lighter than air, and to what use we put them because they are light enough to ascend in the air. That is, they are light enough to allow the air to push them up."

LESSON XVII.

BALLOONS.

ARTICLES for illustration: a small collodion balloon.*

I. A model balloon.

Exp. 92. To inflate a balloon and despatch it to the ceiling is an interesting experiment; but, unfortunately, it is somewhat difficult of execution. The difference between the weight of coal-gas and common air is not sufficient to carry a balloon of less diameter than 18 inches, but a small collodion balloon will ascend if filled with hydrogen gas.†

* These can be purchased at a shilling. Great care must be taken in unfolding, as they are extremely delicate.

† To prepare hydrogen gas place a little of granulated zinc at the bottom of

II. How balloons ascend.

The teacher can make clear to the children the exceeding buoyancy of hydrogen gas in an ocean of air by comparing it with the buoyancy of cork in water. Cork is four times lighter than water, but hydrogen is fourteen and a half times lighter than air. Now cork from its lightness compared with water can be made to hold up or carry up weights

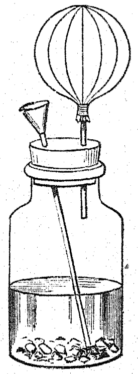

Fig 16.

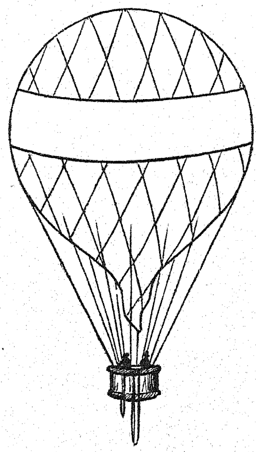

Fig. 17.

in the water [show this by experiment], and just in the same way *balloons are able to carry up weights in the air.*

By comparing the weights of equal volumes of air and hydrogen, it is easy to see that hydrogen has a great lifting power. We have to remember that so long as the balloon,

a bottle (Fig. 16), cover it with water. Insert cork with tubes as in figure. Pour in through the long tube a little sulphuric acid. Hydrogen comes off in quantity. Allow sufficient time for the bottle to be filled with hydrogen to the exclusion of air, and then tie the collodion balloon over the tapering end of the shorter glass tube with a thread of silk. When inflated tie the mouth quickly but firmly. If the gas is required free from moisture and acid it must be passed through water, and a tube containing either lumps of unslaked lime, or of calcic chloride.

the hydrogen it holds, and the weight it carries, weigh less than the volume of air displaced the balloon will ascend, because the lighter body is always pressed up and its place occupied by the heavier body—in this case the air.

Let the capacity of the balloon be 100 cubic feet.

100 cubic feet of air weighs, say	. .	$7\frac{1}{2}$ lbs.
100 ,, ,, hydrogen ,,	. .	$\frac{1}{2}$ lb.

If the weight of the balloon itself is 4 lbs., the carrying power will still amount to 3 lbs., or thereabouts. Of course the larger the balloon the greater the carrying power. Coal-gas is now always used because of its cheapness. Its density varies from one-third to two-thirds that of air; hence its carrying power is much less than that of hydrogen, and the balloon has to be made so much larger.

The teacher may enlarge on the management and uses of balloons: how, when they arrive in rarer air, they are made to ascend still higher, and how the aerial voyager manages to get down again.

⁂ A balloon 18 in. in diameter, made of gold-beater's skin, costs about three shillings; but this can be used many times.

THIRD STAGE.

THIRD STAGE.

Hitherto our lessons have dwelt almost entirely on facts evident to the senses, or made evident by simple experiment. We have now to offer simple explanations of these facts, leaving the more difficult points for consideration in the higher stages. We start with the hypothesis that all matter is made up of *molecules.*

LESSON I.

MOLECULES.

ARTICLES for illustration: mercury, small piece of chamois leather, test-tube, drop of olive oil, &c., according to experiments selected.

The aim of the teacher in this lesson will be to show how minute particles of matter may be divided and subdivided until we can just distinguish them by the naked eye, then only by the aid of a common lens, then with the help of a microscope; and, secondly, to show that we can further subdivide, so that with the aid of the most powerful microscope we fail to detect them, and thus lead up to the still smaller particle—the *molecule.*

(1.) *Exp.* 93. Squeeze a drop of mercury through chamois leather, and let the drops fall on a piece of black cloth. Thousands of the tiniest drops are made from one drop. They are easily seen shining like silver on the black ground. Take one drop, the size of a pin's head. Spread

it over the cloth with the blade of a knife, as you would spread butter on bread. Thousands of tiny drops from this one drop may be seen with a common lens.

Exp. 94. Heat a few drops of mercury in a test-tube. In a few minutes the mercury boils and begins to change to invisible vapour; but as it comes in contact with the cold glass in the upper part of the tube the vapour *condenses* into hundreds of thousands of tiny globes; some join together and become large enough to be seen by the naked eye, while others come into view only with the aid of the magnifying-glass. Here, then, we have mercury divided up, first of all into particles (in the shape of vapour), too small to be seen at all, and then condensing into what seems to the eye the tiniest of silver balls.

(2.) *Exp.* 95. Take a large test-tube, nearly fill it with water, and add *one drop* of olive oil. Shake violently, and we have split the single drop into thousands upon thousands, many of which can be seen under a lens as silvery globes gradually rising towards the surface of the water.

(3.) Water changes to vapour, the particles of which are absolutely invisible under the microscope. It *condenses* into drops (in fog) very small, but not too small to be seen under the magnifying-glass.

(4.) *Exp.* 96. When water is added to a solution of gum-mastic in "spirits of wine," the gum-mastic becomes visible as very fine whitish particles. If we add *one drop* of the solution to half a pint of water, stirring well when we add the drop, the water assumes a milky tinge. This milky tinge is given by the particles of gum-mastic, but they are too small to be seen even under the most powerful microscope.

Now the best microscopes will show solid bodies so small that the hole made in a sheet of paper with the point of a needle will hold many thousands. The particles of gum-

mastic must be smaller still, for they cannot be seen at all.

The teacher may refer also to solutions of solids in liquids; the solids in solution are invisible.

From the above or similar experiments the children will be led to see into what extremely minute particles we can subdivide matter, and they must be told that for reasons of which they will learn more in future lessons, we suppose that *all bodies* are made up of minute ball-shaped particles—particles so minute that it would take millions of them to make the tiniest drop of water we can see. These small particles are called *molecules*, a word which means *little masses*.

LESSON II.

STATES OF MATTER.

ARTICLES for illustration: lead, mercury, water.

If we agree to suppose that all bodies are built up of *molecules*, we can easily explain many facts not otherwise capable of simple explanation.

I. Cohesion.

Take a lump of lead. It is not easy to break. Why? The molecules are held firmly together. Are the molecules tied together in any way? No, but there is some *power* or *force* which holds them together just as if they were tied. If not, what would happen? The lead would break into fine dust. What is the *force* that holds the molecules together? We know not. We only know it is there, and we name it the force of *cohesion*. because the word *cohesion* means *holding together*.

Let us break the lump of lead, and then press the broken ends together. Do they unite and hold together again?

No. How is this? If you could see the broken ends under the microscope you would learn the reason at once. The broken surfaces are rough, and the molecules are not brought near enough to each other to hold together.

Exp. 97. Boys sometimes amuse themselves by cutting a piece off from two bullets; then, scraping the cut faces as smooth as possible, they press them together. The pieces hold together so well that it takes a pretty hard pull to get them apart. How is this? We have brought some of the molecules near enough together to hold on to or *attract* each other.

Sometimes when sheets of glass have been pressed together it has been found impossible to separate them without breaking.

Exp. 98. In the same way if we divide a piece of india-rubber, making a smooth cut with a sharp knife, we can press the cut faces together and make the pieces adhere.

II. Solid, liquid, gas.

We can now better understand the difference between *solids*, *liquids*, and *gases*.

As we saw in the lump of lead, *the molecules in solids are held firmly together.* It is this, in fact, which makes them solids.

Here is a drop of mercury. I just put my finger on it and it is broken into many smaller drops. The molecules of mercury are not held so firmly together as the molecules in lead. It is the same with water: you can break it into pieces with the slightest touch. But is there *no attraction* or drawing together in the molecules of liquids?

I squeeze a drop of mercury between two pieces of glass. It is flattened. I remove the pressure, and the drop becomes a globe again.

I pour a little oil on water; you see the oil floating in drops

I throw water on the floor. The molecules combine to form ball-shaped drops.

If the molecules of mercury, oil, and water did not attract each other they would be spread out.

The molecules of liquids do not attract each other strongly, only just enough to keep together in drops.

In some solids the attraction between the molecules, viz. the force of cohesion—is stronger than it is in others: chalk is more easily broken than flint, and flint than steel. In the same way the force of cohesion is greater in mercury than in water.

A drop of water is spoilt when pressed with the finger; a drop of mercury is not spoilt by a touch, it is only broken into smaller drops.

Why is it that a fine needle laid on the surface of water will float? Because its weight is not sufficient to overcome the cohesion of the molecules forming the uppermost film of water.

As to gas. You will remember that I allowed a bottle of an unpleasant gas to escape and it soon filled the room. How was this? *The molecules of a gas have no liking for each other; on the contrary, they try to get as far apart as possible.* Hence you cannot have a bottle half empty and half filled with gas. The molecules of the gas spread apart and fill the bottle.

LESSON III.

ADHESION.

ARTICLES for illustration: bit of gold-leaf, mercury, water, and any *adhesive* substances.

I. What is the force of adhesion?

In our last lesson we considered the attractive force between molecules of the same kind of matter. In this lesson we have to consider another kind of attractive force.

Place your finger on a piece of gold-leaf; it sticks so firmly that you can neither shake nor pull it off. We say the gold-leaf *adheres* to the finger.

Put your finger in water. It comes out wet. Some of the particles of water *adhere* to the finger.

Plunge your finger into mercury. The finger is not wetted; the mercury does not *adhere*.

With paste, gum, and sealing-wax you can make pieces of paper *adhere*. With glue you can join pieces of wood as well as paper. With mortar and cement you can cause stones and bricks to *adhere*.

This kind of force which causes water to adhere to the finger, gum to stick to paper, glue to wood, and mortar to bricks is called the *force of adhesion*. We may call it a *sticking together* force.

II. Why is it more difficult to stick solids together than it is to stick liquids, or semi-liquids, to solids?

That it is so is seen if we remember how water adheres to the finger, and gum to paper.

Break a stone, a piece of cast iron, or a piece of wood. Feel the broken surfaces. Under the microscope polished surfaces are seen to be rough and uneven, just as we see the broken surface of cast iron with the naked eye.

Solids pressed together can only touch here and there. Liquids flow into all the little hollows and fill them up, and so *adhere* firmly.

III. Why does water wet the finger, while mercury does not?

We have seen in the last lesson that the *force of cohesion* in liquids is not very great. When we put the finger in water there are the two forces of cohesion and adhesion at work. There is the attraction of the molecules of water and there is the attraction between the solid and the liquid. The latter is greater than the former. Some particles of water

leave the other particles to stick to the finger. In the case of mercury the contrary is the case. There is more attraction between the molecules of mercury than there is adhesive power between the finger and the liquid.

Note.—The strength of the adhesion between water and glass may be tested as follows:—

Exp. 99. Suspend a plate of glass from one arm of a scale beam and exactly balance it. Place a dish of water under the plate of glass, so that the surface of the water and the under surface of the glass just come in contact. Several grains may now be added to the weights on the other side without destroying the balance.

By a similar experiment mercury may be shown to have some slight attraction for the glass.

LESSON IV.

CAPILLARY ATTRACTION.

Articles for illustration: capillary tubes, water, mercury, alcohol, and any common porous bodies.

The force of adhesion manifested between solids and liquids explains many of the interesting facts about porous and absorbent bodies which we have noted in former lessons. Before, however, proceeding to these explanations the teacher should repeat some of the former experiments, such as—

1. The absorption of coloured water by salt, chalk, and sugar.

2. The ascent of water or oil in a cotton wick.

3. The ascent of turpentine or paraffin oil in a piece of cane.

The children may now be directed to examine the surface

of water in a very *narrow* test-tube. The surface is level except near the circumference, where the water is curved upward, looking very much like the interior surface of a watch-glass (Fig. 18).

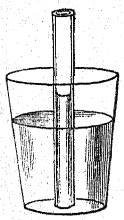
Fig. 18.

Exp. 100. Next place a glass tube with a fine bore in a glass of water: the liquid rises in the tube above the surface of the water in the tumbler. And the finer the bore the higher the water rises in it.

The attraction of adhesion between the glass and the water is best shown in hair-like tubes, that is, with tubes as fine as a hair; hence the attraction is called *capillary attraction.* The word capillary means *hair-like.*

The teacher should now call attention to the ascent of water in sponge, sugar, &c. The pores of sponge, wood, sugar, salt, chalk, blotting-paper, linen, cotton, &c., all form minute, *hair-like* tubes, in which the water rises by *capillary attraction.*

Further illustrations of capillary attraction may be found in the water rising from a saucer through the hole in the bottom of the flower-pot, whence it passes, the stems and leaves of the plant; and in the luxuriant vegetation of the river margin.

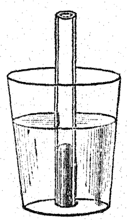
Fig. 19.

Exp. 101. The teacher may lastly test the adhesive force between glass and alcohol, and between glass and mercury, in minute tubes. The alcohol does not rise so high as the water, and the mercury does not rise at all; on the contrary, it is depressed below the level in the glass, and its surface is of the same shape as the outside of a watch-glass (Fig. 19). Why is this? Simply because the force of adhesion between the glass and the mercury is less than the force of cohesion between the molecules of the liquid metal.

LESSON V.

PROPERTIES OF SOLIDS EXPLAINED.

ARTICLES for illustration: specimens used in preceding lessons for illustrating the more common properties of bodies.

By various experiments on common solids, such as breaking, bending, pressing, scratching, hammering, and so on, the teacher will lead the children to see that the *force* and *kind* of cohesion in the molecules *is very various*, and gives rise to the special *properties of solids.*

I. Hardness.

Iron can be broken only with difficulty, marble requires a sharp stroke with a hammer, chalk can be broken with the fingers; evidently, then, the cohesive force must be very different in these bodies.

The teacher will call on the children to tell how we compare the hardness of solids [see Lesson X., page 18] and if the class is sufficiently advanced he may introduce the "scale of hardness" as given below.* In this table each substance marked with a lower number will scratch one marked with a higher number. Thus topaz (3) will scratch quartz (4), and quartz (4), in its turn, will scratch felspar (5). If we find a substance which will scratch felspar, but is able in its turn to be

* SCALE OF HARDNESS OF BODIES:—

1.	Diamond	cannot be scratched with a steel file.
2.	Corundum	
3.	Topaz	
4.	Quartz (flint)	
5.	Felspar	can be scratched with a steel file.
6.	Apatite	
7.	Fluor-spar	
8.	Calc-spar	
9.	Rock salt	can be scratched with the finger-nail.
10.	Talc	

scratched by quartz, we say the hardness of the body is between 4 and 5.

II. Flexible and brittle.

Question as to these properties. Bend a strip of cork. It is clear that the molecules on the upper side must be pulled a little farther apart than usual, while those on the under side must be pressed closer together. Such bodies as can be bent without breaking are said to be *flexible*. In some bodies the molecules will not bear this change of position—they part asunder. Such bodies are said to be *brittle*.

III. Elastic.

The teacher should first question on the different ways of testing the elasticity of solids (see Lesson XII., page 21). In an elastic body the molecules will bear not only to be pressed or pulled from their usual position; but, on the force being removed, will return to it again.

There is a limit, however, to the elasticity of bodies, and if the force applied exceeds a certain limit the form of the solid may be permanently altered. Thus the elasticity of springs of carriages may be permanently injured by overloading.

IV. Malleable, ductile, and tenacious.

Hold a thin tube of soft glass in the flame of the spirit-lamp. It does not melt, but it softens so that it can be flattoned, or drawn out into fine threads. How is this? We displace the molecules, making them take up different positions without destroying their cohesion. So it is with certain metals: we may hammer them out into thin leaves, or draw them out into fine wires without destroying the force of cohesion in their molecules. Such metals are *malleable* or *ductile*. That a metal may be ductile, it is evident that its molecules must possess a strong cohesive force, or breakage would follow.

Metals which possess this strong cohesive force are said to be *tenacious.*

A metal cannot be ductile without being tenacious. It may, however, be tenacious without being ductile. Platinum is the most ductile metal, gold is the most malleable.

LESSON VI.

FORCE OF GRAVITY—WEIGHT.

ARTICLES for illustration : a few heavy and light substances.

I. Meaning of "up" and "down."

"I throw a ball in the air over my head. In what direction do you say it goes?" *Upwards.*

"And in what direction does it return?" *Downwards.*

"A boy shall lift this piece of iron. If he looses his hold, where will the iron go?" *To the floor.*

"And supposing the floor were not there?" *To the ground.*

"What do you mean by the ground?" *The surface of the earth.*

"You all know the general shape of the earth; what is it?" *Round like a ball, or an orange.*

"And I dare say you know that New Zealand is on the other side of the globe, just about opposite to us.

"Now if a teacher were giving the same lesson in a school in New Zealand that I am giving you at this moment, and he asked a boy to let fall a piece of iron from the table, in what direction would the iron fall?" *Downwards to the ground.*

"But has *downwards* the same direction in New Zealand that it has in England? Let me help you to find out.

"Here I draw a circle on the blackboard to represent the

earth (Fig. 20). Suppose a man in a balloon, in the position which I mark A, throws out a stone, where will it go?" *To the ground.*

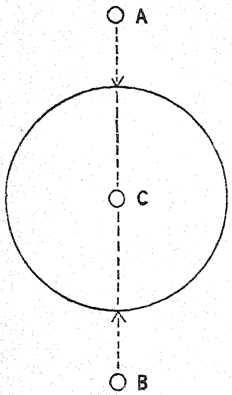

Fig. 20.

"Now suppose a man to be up in a balloon on the opposite side of the earth, and he should let fall a stone, where will the stone go?" *To the earth.*

"But will the stone travel in the same *direction* as the first one?" *No, in the opposite direction.*

"If there were no solid earth in the way, where would the stones meet?" [Look at the lines.] *At the point marked* C. "And this point is the centre of the earth. Just in the same way, wherever a body is let fall it falls towards the centre of the earth.

"What does *down* mean, then?" *Towards the centre of the earth.*

"And what does *up* mean?" *Away from the centre of the earth.*

II. Gravity or weight.

"Now we have to inquire, what is it that causes bodies, when let fall from a height, to go towards the centre of the earth? *The earth attracts or draws everything towards itself. How* this is done we do not know. That it *is* done is proved every time we lift a weight, or throw a stone.

"I ask a boy to hold this piece of iron in one hand, and this piece of cork of about the same size in the other. What has he to note about these substances?" *Iron is heavier than the cork.*

"What makes the iron heavier than the cork? I will tell you. It is because the earth draws the iron more strongly than it draws the cork. It is, in fact, the force with which

the earth draws everything towards itself that makes *weight*. And we name the force the *force of gravity*, because the word *gravity* means *heaviness*."

III. Explanations.

A knowledge of this *force of gravity* helps us to explain many facts in nature.

1. Why is lead heavier than wood? In other words, why does the earth attract a piece of lead more than it attracts a piece of wood of the same size?

The molecules in the lead are closer together than the molecules in the wood. There is more substance in the lead than in the wood.

2. Why does stone sink in water, and why does wood float? Because the earth attracts the stone with more force than it does the water, and the water with more force than the wood.

3. Molecules of gas are always trying to get farther and farther apart. Why then do they not get apart altogether and fly away into space? Because the earth attracts them, and when the force of gravity is equal to the repellent force between the molecules the gas cannot get any farther away from the surface of the earth.

NOTE.—The time of another lesson may be profitably spent in reviewing these various attractive forces. Other kinds of attraction are referred to in future lessons, and the attraction of gravitation is more fully explained.

LESSON VII.

THE SURFACE OF A LIQUID AT REST IS ALWAYS LEVEL.

ARTICLES for illustration:—various glass vessels, and, if possible, a "spirit-level."

I. Molecules of water.

We saw in the last lesson that the properties of solids depend

on variations in the force of cohesion between the molecules In liquids the force of cohesion is but slight, almost nothing, and it is to this fact that the peculiar properties of liquids are due. In fact, the difference between solids and liquids may be thus expressed, that in solids the force of cohesion is greater than that of gravity, while in liquids the force of gravity is very much greater than that of cohesion.

We have, then, to *imagine* that water is made up of globes, so exceedingly fine that it takes millions to form a single raindrop. Further, these molecules must be so smooth and round that they move about and amongst each other with the greatest possible ease.

It may be asked why we think they are round and smooth. It is because if they were rough, or had corners or points, they could not move about among each other so easily as they do. We cannot roll blocks or nails about as we can shot; and the smoother the shot the easier it is to move them about.

If the molecules of water were large enough for us to see them, the surface of still water would look like a level layer of fine, clear, and colourless shot; and whenever there was the least motion in the water we should see the tiny molecules rolling about amongst each other with perfect ease.

II. Water always tries to find its level.

We seldom see still water. As it moves so easily, it is nearly always in motion. The wind raises it into waves and ripples. It runs in streams and rivers, and wherever water is in motion it is simply trying to return to a level.

Exp. 102. The teacher may illustrate this with a basin of water. The surface is level as the basin rests on the level table. Raise the basin at one end, the water runs a little to the lower side, and becomes level again.

Exp. 103. Water is always at the same level in the teapot, or the garden watering-pot (Fig. 21, 1.)

If the watering-pot be turned up as in Fig. 21, 2, the

level is still kept, but when turned up a little more, as in Fig. 21, 3, the water in the spout in trying to get on a level with that in the pot runs out.

The teacher may use various glass vessels, and by placing

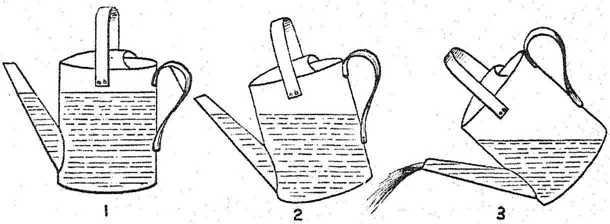

Fig. 21.

them in different positions show with sufficient accuracy for our present purpose that when *the liquid is at rest the surface is level.*

He may also show an interesting application of this property of liquids in the common *spirit-level.*

LESSON VIII.

PRESSURE IN LIQUIDS. I.

ARTICLES for illustration: a few glass marbles, a bag of small shot, a lamp chimney, and a boy's sucker.

I. Pressure downwards and sideways.

"What is weight?" *Pressure downwards. Pressure towards the centre of the earth.*

"I place a lump of lead on the table; in what direction does it press?" *Downwards.*

"Is there any pressure sideways or upwards?" *None.*

"Why?" *Because the attraction of cohesion among the particles is stronger than their gravity, or attraction towards the earth.*

Exp. 104. "Here is the tube which we used in a former lesson (see page 36). I set it upright and place this iron rod in it. Does the rod press on the sides?" *No.*

"I fill the tube with water. Now if I make a hole in the side of the tube, what will happen?" *The water will run out.*

"What does that show about the water?" *That water presses on the sides of the vessels which hold it.*

"Liquids then differ from solids in this, that they exert a pressure sideways as well as downwards. Solids press only downwards. I will endeavour to explain how this comes about.

"Tell me what we learnt about the molecules of water in the last lesson." *They are very minute. They are round and smooth. They move about amongst each other with perfect ease.*

Exp. 105. A little experiment will now help us to see how water presses sideways.

Take three marbles, place them side by side in the shape of a triangle on the smooth table, or on a piece of glass. Now put a marble on the top; what happens? Those below are pressed out sideways.

And this is just what happens with the fine "water-balls" only the water-balls are so much smoother than the marbles that they move much easier.

Exp. 106. The teacher may further illustrate by making a hole in a bag of small shot. The shot close near the hole will be pressed out by those above, and these in their turn will be pressed out by those above them, and so on. Just so it is with the delicate *water-shot.* They are pressing down, and so pressing sideways those below. And if an opening is made in the side of the vessel that holds the water, the molecules near the opening will roll out like the shot, only a great deal easier because so much smoother.

II. Pressure upwards and in every direction.

(*a*) Thrust your hand into a vessel of water. You press some of it down, but not all of it. Some of it is pressed upwards, for you see it is higher in the vessel.

(*b*) *Exp.* 107. Place a flat piece of cork on the surface of water and try to press it down. Or, take an air-ball and push it down into the water. You find it difficult to push the cork or the ball beneath the water. Why? Because of an upward pressure.

(*c*) Pour water into a coffee-pot. Some of it is *pressed up* the spout till the liquid in the pot and in the spout have the same level.

(*d*) *Exp.* 108. Cover one end of a glass cylinder—a lamp chimney will answer the purpose—with the leather of a boy's "sucker," and let the string pass upwards through the chimney. Hold the leather firmly against the base of the chimney, and lower carefully into a jar of water. Drop the string, and the leather is held in place by the upward pressure of the water (Fig. 22).

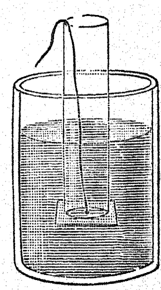
Fig. 22.

It should of course be noted that this upward pressure in liquids operates only up to the natural level of the surface and not beyond. At the surface there is no upward pressure.

This upward pressure in water explains why solids weigh less in water than out of it.

Water, then, presses downwards and sideways and upwards. *It presses in all directions.*

LESSON IX.

PRESSURE IN LIQUIDS. II.

ARTICLES for illustration: chimney-glass and boy's sucker, hollow india-rubber ball, and bent glass tubes as in Fig. 23, glass vessel for holding water.

I. Pressure increases as the depth increases.

It is quite certain that the pressure *downwards* in a column of water must increase with the depth, for a tall column must be heavier than a shorter one.

Exp. 109. The teacher may next show that the pressure *sideways* increases with the depth by the tube as described on page 36.

The chimney-glass and boy's sucker (see the preceding Lesson) will serve to show that pressure upwards increases with the depth.

Press the chimney-glass a short distance into the water. Pour water into the chimney-glass and note how tall a column of water is required to overcome the upward pressure and set free the sucker.

Remove the glass from the water, and again holding on the sucker, press down further into the water. Pour water into the chimney until the sucker is released, and compare this column of water with the previous one. It will be longer, and therefore heavier. Why must it be longer and heavier? Because it has to overcome a greater upward pressure. And it will be found that the deeper we press in the chimney-glass the greater will be the upward pressure on the leather sucker.

Sailors sometimes amuse themselves by partially filling a bottle with water and then after corking it tightly, letting it down by means of a long string into deep water. The great pressure of the water forces in the cork, and the bottle

comes up full of water. No matter in what direction the neck of the bottle may point when let down, the result is the same. This shows that the water presses with equal facility in all directions, and that, deep down, the pressure is much greater than near the surface.

II. At the same depth the pressure is equal in all directions.

Exp. 110. Take two glass tubes bent as in Fig. 23. Put mercury in the lower part of each tube, so as just to fill the short arms. Lower both tubes into a glass vessel of

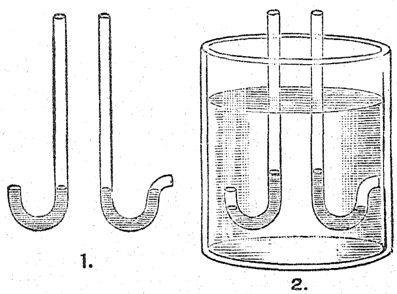

Fig. 23.

water. The water will force the mercury up the longer arm of each tube, and if the mouths of the short arms are at the same level, the mercury in the long arms will stand at the same height, showing that the downward pressure and the side pressure are equal.

III. Liquids transmit pressure.

The teacher will first explain the meaning of the word *transmit.*

Exp. 111. Then take a hollow india-rubber ball having a hole in it, and fill with water. Prick the ball with a needle in several places. Close the large hole with the thumb, and squeeze the ball. The water will issue forth in tiny jets in every direction, showing that the water transmits in every direction the pressure put upon it.

LESSON X.

BUOYANCY OF LIQUIDS.

ARTICLES for illustration: pieces of cork, sponge, wood, and metals, salt, an egg, mercury, and spirits of wine.

I. Buoyancy of water.

The teacher may take a hollow india-rubber ball, a piece of cork, or a bladder filled with air, and direct some of the scholars to press the object down beneath the surface of water in a bucket or tub.

Some effort is found necessary to press it into the water. The children can feel that there is an upward pressure. This upward pressure is called the *buoyancy*, or *floating power* of water.

Bodies which swim about *partly* below the surface of the water are said to float.

Some bodies, such as cork and dry sponge, sink very little into the water. The floating power of the water prevents their sinking far down. These are *very light* bodies. Other substances, such as wood and india-rubber, sink farther into the water. These are heavier bodies, and the floating power of the water—the pressure upwards—is unable to do more than just keep a small part above the surface. We say that wood and india-rubber are *light* bodies.

Other bodies again, such as stone and iron, overcome the floating power entirely and sink to the bottom. Such we may call *heavy* bodies, but they vary very much in weight.

The teacher may here refer to the special uses of light bodies, such as *cork* for life-buoys and lifeboats, *wood* for ship-building, and so on.

II. Buoyancy of other liquids.

Exp. 112. Take a small cup of mercury and place a lump

of iron on it. The iron floats. Why? Because mercury is heavier than iron, and has so much greater floating power than water. The teacher may direct the children to put cork, wood, copper, and any other articles on mercury. Lead, copper, tin, silver, and iron, all float on mercury. Gold sinks to the bottom. Why? A fact the children should remember is that the heavier the liquid the greater the floating power. Therefore it is easier to swim in salt water than in fresh. And in the water of the Dead Sea, which is very salt, it is impossible to sink.

Exp. 113. Here is another interesting experiment showing that the heavier liquid is the more buoyant. Place a new egg in fresh water, and it sinks to the bottom. The downward pressure of the egg caused by gravity is greater than the floating power of fresh water. Now put the egg in strong brine and it floats near the surface of the liquid. Why? The buoyancy of brine is a little more powerful than the pressure downwards due to gravity. Placed on mercury the egg seems to sink scarcely at all. Why?

Now take a lighter liquid, like spirits of wine, and it will be found on trial that cork or wood sinks deeper into this liquid than it does into water. Why?

III. Applications.

The children will now be able to answer such questions as the following:—

1. Why does a stone weigh less in water than it does in the air?

2. Why does a person find it difficult to stand upright in water sufficiently deep to cover the shoulders?

3. How is it that a man can float near the surface of water?

4. Why does ice form at the top, and not at the bottom of water?

5. Why does oil float on water?
6. Why does cream rise upon milk?

LESSON XI

WEIGHT OF THE ATMOSPHERE.

ARTICLES for illustration: test-tube, glass tube closed at one end 30 inches long with small bore, mercury, water, and a couple of small cups.

I. Weight of air.

The teacher should refer to Lesson VI., page 83, and from this infer that the air, being attracted by the earth, must have weight.

Next the teacher should describe how the air may actually be weighed. Exhaust* the air from a large bottle; weigh it; allow the air to enter, and re-weigh. The bottle full of air will be found to be considerably heavier than the empty bottle.

A cubic foot of air weighs a little more than an ounce.

But an *ocean* of air many miles in thickness covers and surrounds the earth. There is air on the top of the highest mountains, and men who go up four or five miles in balloons find air, or they could not live. As you will learn in another lesson, the air gets thinner and thinner as we ascend, but it probably reaches for forty or fifty miles or more before it comes to an end.

II. Weight of a column of air.

We have now to ask and answer the question, what is the weight—in others words, what is the pressure on the earth—of a column of air extending from the earth to its extreme limit above the earth?

* See page 50.

Exp. 114. Fill a test-tube with water; invert it with the mouth under water in a shallow sauc r (Fig. 24). The test-tube is full of water. But water always runs down if it can. What keeps it up in the tube? It is kept up by the pressure of the air on the water in the saucer. If we could take away* all the air from round about the tube the water would fall; there would be nothing to keep it up.

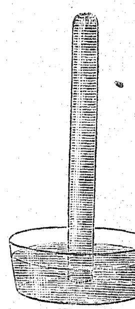
Fig. 24.

Exp. 115. Now instead of the test-tube let us use a tube open at both ends, only we cover one end tightly with a piece of wet bladder (Fig. 25). Now fill and raise as before. So far this is the same experiment as the last; but now prick a hole in the bladder. The water runs down, because the air has got at it and forced it down.†

If we could use a tube about 33 feet long we should find that the pressure of the air would keep the tube full of water; but make it about 34 feet long and the water would sink one foot in the tube. Hence the air can support a column of water of any length up to 33 feet, but no more. What do we learn from this? That the weight of the air is sufficient to balance a column of water 33 feet high, but not a column 34 feet high.

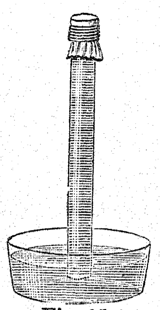
Fig. 25.

It is not easy to experiment with tubes so long, although such tubes have been made for the purpose of testing this weight or downward pressure of the air.

It is more convenient to use mercury. This metal is about $13\frac{1}{2}$ times as heavy as water, and so we must divide 33 feet

* This can be done under the receiver of an air-pump.
† A cork, or the palm of the hand, may be used instead of the bladder.

by $13\frac{1}{2}$ to find the length of a column of mercury equal in weight to a column of water 33 feet high, both being held in tubes of the same diameter. It will be found to be between 29 and 30 inches.

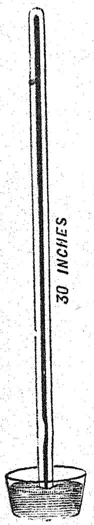

Fig. 26.

Exp. 116. Take a tube about 30 inches long—with small bore, because less mercury will be required—closed at one end. Fill the tube by pouring in mercury. Place the finger firmly over the open end. Invert and place in a small cup of mercury (Fig. 26). The column of mercury will be supported by the weight, or pressure downwards of the atmosphere.

Notice, we say the column of water is *about* 33 feet long, and the column of mercury is *about* 30 inches. You will learn the reason for this in a future lesson; but I may now just tell you that the weight of the atmosphere is not always the same. It changes a little day by day, so that sometimes it will support a column of mercury 31 inches high, and at other times perhaps only 29 inches, or even less.

We can now easily find the actual weight of a column of air of any size, reaching from the surface of the earth to its utmost limit above.

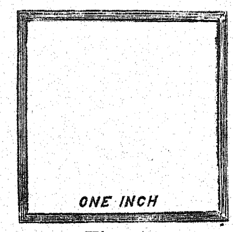

Fig. 27.

Take a tube square in section, and each side of the square measuring an inch (inside measure) (Fig. 27); we may say that the tube has a base of *one square* inch. Now the mercury which just fills a tube of this size and 30 inches long weighs about 15 lbs., and as this can be supported by a column of air of the same size, we conclude that the column of air weighs 15 lbs. It is more usual to say, *The atmosphere*

presses on everything with a force equal to about 15 lbs. on the square inch.

LESSON XII.

PRESSURE OF THE ATMOSPHERE.

ARTICLES for illustration: boy's sucker, tumbler, water, and a thin card to cover mouth of tumbler.

The teacher should refer back to Lesson VIII., page 51, and repeat one or two of the experiments to show that *air presses in all directions.*

Secondly, he should refer to Lesson IX., page 91, where it is shown by experiment that, *at the same depth,* the pressure of water is equal in all directions.

The atmosphere presses with equal force in all directions, when measured at the same distance above the level of the sea.

The same law holds good in all fluids, including, of course, the air; but we cannot prove it in the atmosphere by simple experiment because we cannot easily get to different heights.

The law *must* be true at the surface of the earth. We have seen that the pressure of the air on every square inch is about 15 lbs., hence the pressure on a square foot will be more than *a ton.* The pressure, then, on the bottom of an "empty" bucket measuring a square foot will be over a ton. How, then, can we lift the bucket? Just because the pressure upward is equal to the pressure downward, and we fail to feel the pressure of the air at all. Pressure sideways, too, must balance or we could not stand upright.

The pressure of the atmosphere on every child in the class is several tons; but it is not felt because there is an equal pressure outwards from the air within the body.

[If an air-pump can be obtained, the great pressure of the

atmosphere can be demonstrated in a variety of ways. See Lesson XVIII., page 111.]

If the air which surrounds the earth had the same density* everywhere, it would follow that, as we ascend, a given column would become just as much lighter as it is shorter; but the air is by no means of the same density everywhere. It could not be, because it is very compressible, and the air above must squeeze the air below into less space by its weight. Therefore the air near the sea level is much heavier than the air at a great height.

We may compare roughly a column of air to a column of bales of wool. The bales near the bottom will be squeezed, and made thinner than those above (Fig. 28).

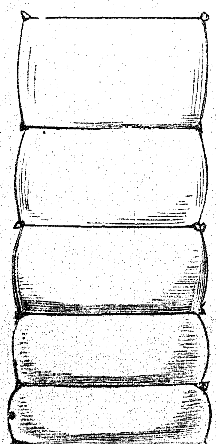

Fig. 28.

If we go to the top of a high mountain we leave the denser part of the air below us; and a column of air should weigh much less at the top than it does at the base of a mountain, and so it does. The weight is lessened much more rapidly than the length of the column above us.

At the top of Snowdon the column with square inch section weighs about 13 lbs. instead of 15 lbs. At the top of Mont Blanc the column weighs only $7\frac{1}{2}$ lbs This is shown by the height of a column of mercury which the air supports.

For every *thousand feet* we ascend the column of mercury *shortens* by about *one inch.* But if the air were equally dense everywhere, we should have to ascend more than a mile before the mercury fell as much as this.

On the other hand, if we descend into a mine the column of mercury *lengthens one inch* for every *thousand feet.*

* Thickness, closeness, the same number of molecules occupying a similar space.

LESSON XIII.

THE BAROMETER.

ARTICLES for illustration: a narrow tube thirty-four inches long, a shallow cup, and enough mercury to fill the tube and two-thirds of the cup.

I. The weight of the atmosphere very much varies with the amount of water-vapour it contains.

"Not only does the weight of the atmosphere vary according to the height above the sea level at which it is measured, but it varies, as I have already told you, from day to day, and even from hour to hour, at the same place. To what is this variation due? It is due to two or three causes, but mainly to the variation in the quantity of vapour in the air.

"The atmosphere is a mixture of certain gases and *vapour*, and you know that vapour is lighter than air. How do you know that vapour is lighter than air?" *Because it ascends in the air.*

"Then which will be the heavier, dry air or a mixture of air and vapour?" *Dry air.*

"And how will the weight of the mixture vary?" *It will vary as the quantity of vapour in the atmosphere varies.*

"When will the mixture be heaviest?" *When it contains the least amount of vapour.*

"And when will it be lightest?" *When it holds the largest quantity of vapour.*

"Now you can tell me when the mercury in our column will stand highest." *Omitting other conditions, when the atmosphere contains the least amount of vapour.*

"And when will the column be shortest?" *Omitting other conditions, when the air contains the largest amount of vapour.*

"The height of the column of mercury then shows two facts. What are they?" *Roughly the pressure of the atmosphere at any given time; and to some extent the amount of moisture in the atmosphere.*

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II. Construction of barometer.

Exp. 117. The teacher may now take a tube of narrow bore 32 or 33 inches long and closed at one end. Fill with mercury. Place the finger firmly over the open end, and invert in a small vessel of mercury (Fig. 29).

Now call the attention of the children to what happens. The mercury falls, and there is a vacuum of two or three inches. Paste a narrow strip of paper on the upper part of the tube.

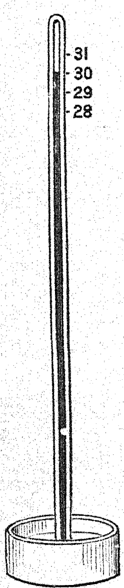

Fig. 29.

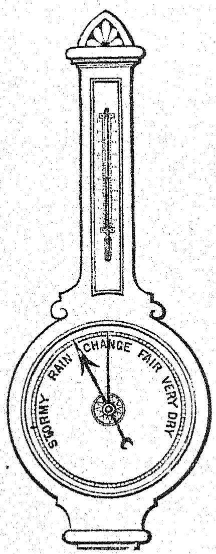

Fig. 30.

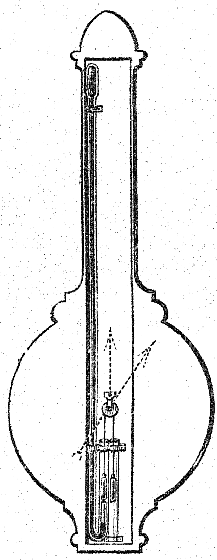

Fig. 31.

Measure from the surface of the mercury in the vessel to the surface of the mercury in the tube. It measures, say 30 inches. Mark this on the paper. Also mark 28, 29, and 31 inches, and tell the children that, looking at the tube day after day, we shall find the column of mercury changing its height; sometimes it will be as low as 28, and sometimes as

high as 31 inches, but that its more ordinary height is between $29\frac{1}{2}$ and $30\frac{1}{2}$ inches.

The children will see that the simple tube and vessel without support would be a very awkward instrument to stand in our houses, and the teacher may show how they are fixed in a frame. He may also show how the "wheel-barometer" works. [See Figs. 30 and 31.]

III. The barometer an indicator of weather.

We see, then, that the mercury in the glass tube *measures* the *weight* of the atmosphere. The word *barometer* means a *measure of weight*, and so we call our little apparatus a *barometer*. The barometer is a very useful instrument, because as it measures the weight of the atmosphere it also indicates something of the amount of moisture in it. Now much moisture means *it is likely to rain*, and little moisture means *we shall probably have fine weather*. That is, the barometer tells *something* of the kind of weather we are likely to have. When the mercury "falls" it usually betokens *rainy weather*, when it "rises" it usually points to *fair weather*. When the mercury falls very quickly it often betokens a severe storm.

LESSON XIV.

THE SYRINGE.

ARTICLES for illustration: long glass tubes, one straight and one bent, with rather small bore; a syringe of any kind.

I. Its parts.*

Consists of tube with small hole at one end, a piston-rod and a sucker. The teacher should take his specimen syringe to pieces and show its parts.

* The teacher may construct his own syringe. Take a glass tube eight or nine inches long, with about a half-inch bore. Fix neatly into one end a short cylinder of wood with a small hole through the centre. Take a straight rod for piston, and bind worsted round one end to make the sucker.

II. Its action.

Exp. 118. See that the piston-rod is pressed down. Place the point of the syringe beneath the surface of the water. Draw up the piston-rod; the water follows the sucker. Press the rod back and the water is pushed out in a stream through the small hole.

Fig. 32.

Why does the water enter the cylinder when the piston-rod is drawn back? And why does it require a small hole, or holes, through which to force the water.

It is commonly said that the sucker sucks up, or draws up, the water; but this cannot be, as I will show you.

Exp. 119. Take this glass tube, place one end in this bottle of water and the other end in your mouth. Now "suck up" the water through the tube. What makes the water come through the tube into your mouth? I will tell you. You "suck out" the air, and the water follows. But the water cannot move of itself, something must force it up the tube. It is the air pressing on the water in the bottle. I will now prevent the air from pressing on the water in the bottle. I pass the tube through a hole I have made in this cork and cork the bottle. Both tube and cork must fit tightly. Now try and suck up the water. You cannot. Why? Because although you remove the air from the tube, the water cannot follow, there being no force to push it up.

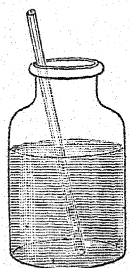

Fig. 33.

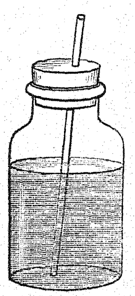

Fig. 34.

Exp. 120. We may show the same thing another way. Here is a bent tube. I partly fill it with water (see Fig. 35).

So long as I leave the short end open I can drink the water; but when I place my thumb firmly over this end I can no longer get the water to ascend the longer leg.

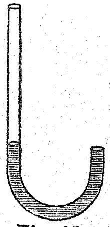

Fig. 35.

Precisely the same thing happens in the working of the syringe as in the oottle when not corked. The sucker removes the air, or the greater part of it, from the cylinder, and the pressure of the air on the surface of the water in the vessel forces the water into the syringe.

Exp. 121. To answer the second question the teacher will fill a test-tube with water, and, placing a disc of paper over its mouth, invert. The upward pressure of the air keeps the water in its place. If I remove the paper I don't remove the pressure, and yet the water falls out. It falls out because the gravity of its molecules is greater than their cohesion; and when there is nothing to preserve the level surface of the water, the air breaks in and forces itself up among the particles, and actually turns the water out to take its place. Small holes are used in the syringe because they allow but a small water-surface for the air to act upon, and so the water does not run out freely unless pressed by the sucker.

III. Its uses.

Watering plants, cleansing their leaves. For cleansing our ears, &c.

LESSON XV.

THE COMMON PUMP.

ARTICLES for illustration : a glass model of a common station-pump;* or the teacher may sketch on the blackboard (Fig. 39).

I. Its parts.

Like the syringe, the common pump consists of a cylinder

* This can be purchased for about two shillings.

and a piston with sucker; but, unlike the syringe, it has little doors working on hinges, which we call *valves.*

The teacher should, at the outset, explain the working of

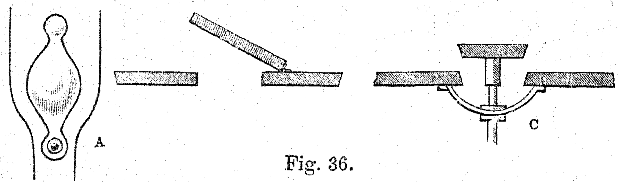

Fig. 36.

valves, sketching the shapes of two or three of the most common on the blackboard (Fig. 36, A, B, C).

The valve (Fig. 36B) is the one most often used in the common pump. It is called the bellows valve, because used in the common bellows.

When you pull the handles of the bellows apart, as shown in Fig. 37, you make more room in the bellows, and the air forces the valve open and rushes in to fill up this space.

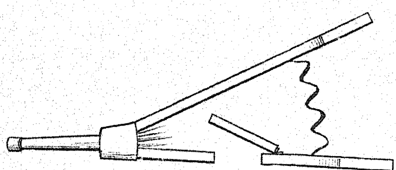
Fig. 37.

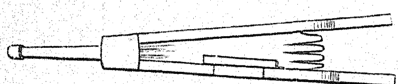
Fig. 38.

When you push the handles of the bellows together, as in Fig. 38, you compress the air, and it closes the valve and rushes out in a stream through the nozzle.

The teacher will next show the class the position of the valves in the model, or in the sketch. He should also draw attention to the fact that the lower part of the cylinder, or the *suction-pipe*, is smaller than the upper part, commonly called the *barrel.*

II. Its action.

In Fig. 39A the pump handle is down, and consequently

the sucker is as high as it can be raised. Both valves a. closed.

Raise the handle. The air between the sucker and the lower valve will be compressed, consequently it will force open the valve in the piston and escape above. When the

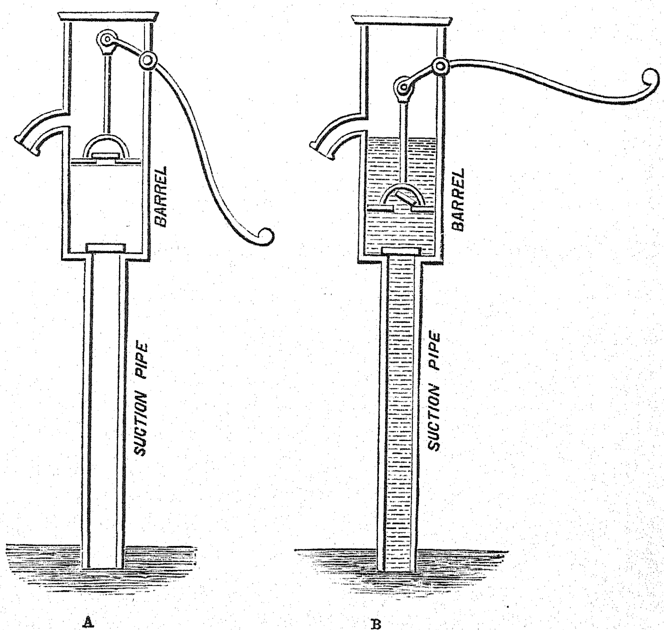

Fig. 39.

sucker is at its lowest point this valve will be again closed by the weight of the air above it.

Press the handle down. The valve in the piston is kept closed by the downward pressure of the air, and the space between the piston and the lower valve will be deprived of the greater part of its air. The air in the suction-pipe, by its elasticity, will open the valve, and part of it will escape into the "empty" space in the barrel. It follows that the pressure of the thinner air on the water within

the suction-pipe will be less than the pressure outside, and then the water will be forced by the outside pressure up the suction-pipe until the pressure outside and inside are equal.

Repeat the action with the handle, and the water will rise higher in the suction-pipe, till after a few strokes it forces open the lower valve and enters the barrel.

When we raise the handle again the piston presses upon the water and forces it up through the valve in the piston (see Fig. 39B). The next down stroke actually lifts the water, and when sufficient is raised above the sucker it flows out through the spout.

The teacher will now show the class that the principle of the pump is just the same as that of the syringe, or of "sucking" up water through a small tube. It is the weight of the outside air which presses up the water in the suction-pipe.

What is the length of a column of water which the pressure of the atmosphere will sustain? From 33 to 34 feet. Then we cannot raise water with an ordinary pump from a greater depth than 33 or 34 feet. As a matter of fact we cannot raise it so high, because we fail to keep out all the air. The average is about 27 or 28 feet.

III. Its uses.

The teacher will give the uses, *e.g.* raising water from wells, draining mines, &c.

LESSON XVI.

FORCE-PUMPS.

Articles for illustration :—Models of force-pumps are rather expensive, and the teacher will probably have to substitute diagrams on the black-board.

I. Force-pump.

Fig. 40 represents a very simple form of the force-pump.

The action, while the piston is ascending, is like that of the common pump. In descending the action is different. There is no valve in the piston. This is placed somewhere in the discharge pipe which leaves the barrel near the bottom.

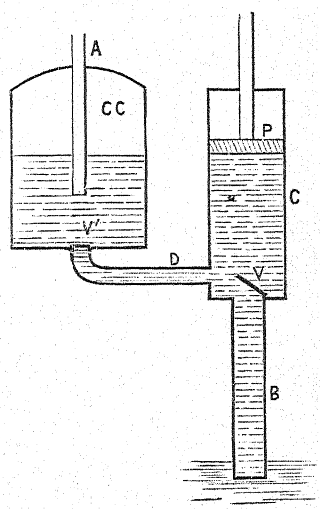

Fig. 40.

In the diagram B represents the suction-pipe, C the barrel, P the piston; D is the discharge pipe from the barrel, V and V′ are valves opening upwards, CC is the "condensing" chamber, and A is the discharge pipe into the air.

When the piston is raised the water is forced up by the atmospheric pressure outside into the suction-pipe, and thence, after a few strokes, into the barrel. When the piston is pressed down the valve V closes and the water is forced through the pipe D and into the chamber CC. This chamber at first is full of air; but after a few strokes of the piston this air is compressed by the water forced in.

The compressed air in its turn presses on the water and forces it out through the tube A—which is smaller than D—in a continuous stream.

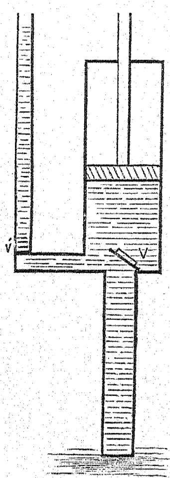

Fig. 41.

II. The lifting pump.

The working of this pump can be seen at once from the diagram (Fig. 41).

Water may be pressed up, or lifted, to almost any height

in the small tube, provided sufficient force is exerted on the piston, and the machine is strong enough to bear the pressure.

III. The fire-engine.

The fire-engine is a kind of force-pump. Fig. 42 represents the hand fire-engine. It is a *double* force-pump of the kind

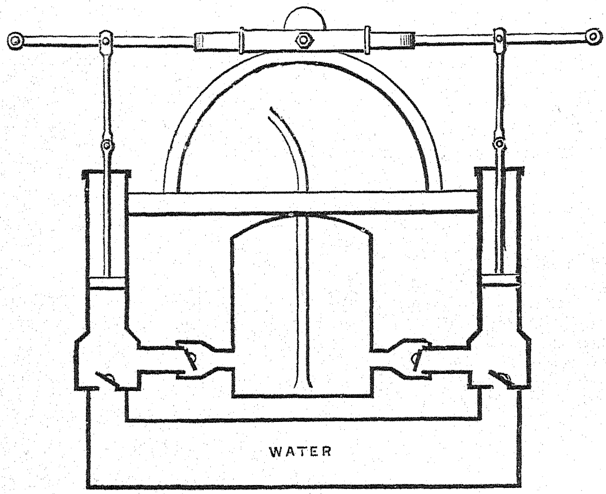

Fig. 42.

shown in Fig. 40, and its action is precisely similar. The water is forced alternately from either cylinder into the central, or condensing chamber.

LESSON XVII.

THE SIPHON.

Articles for illustration : bent glass tubes. [See cuts.]

I. Experiments with water in bent tubes.

Exp. 122. Take a narrow glass tube (say $\frac{3}{16}$ inch bore)

about eight inches in length, and bend it as shown in Fig. 43. Fill the tube by immersing in water. Raise it gently out of the water; the water does not run out of either end so long as the tube is kept upright. Or the points of the fore-fingers may be placed over the ends whilst lifting out of the water.

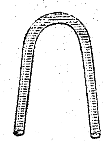

Fig. 43.

Exp. 123. Next take a wide tube bent in the same way, with legs of equal length. Place the open ends upwards and *fill* the tube with water. Place a thin card over each end and invert (Fig. 44). So long as the legs are kept upright the water does not run out. But if the tube be inclined either way the water runs

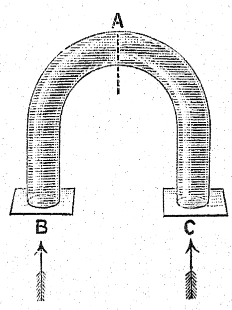

Fig. 44.

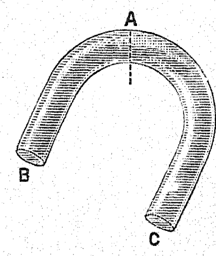

Fig. 45.

out of the *lower* end. When we incline the tube we make one leg longer than the other (Fig 45).

II. Action of the siphon.

(*a.*) *How is the water retained in both legs of the tube when the legs are of the same length?*

(*b.*) *When we make one leg longer than the other, why does the water run out at the lower end?*

A few questions on the pressure of the air in every direction will lead the children to see that the pressures upwards

on B and C (Fig. 44) are equal. There is also a downward pressure on B and C, *viz.* the weight of water in each leg. And this will be equal when the legs are of equal length. [That is, of course, provided the tube is of the same bore throughout.]

Suppose these pressures of the air upwards to be equal to a weight of 4 lbs. on each leg, and the pressure of the water downwards in each leg to be half a pound. Then this just amounts to the same thing as a pressure upwards on the water in each leg of $3\frac{1}{2}$ lbs., and the one pressure just balances the other.

Exp. 124. Next suppose one leg to be twice the length of the other (Fig. 46). The pressures upward as before will be equal, say equal to a weight of 4 lbs. on the water in each leg. But the pressure downward in the longer leg will be double that of the other. If the water in the shorter leg weighs $\frac{1}{2}$ lb., then the water in the longer leg weighs 1 lb. This amounts to the same thing as a pressure upwards on B of 4 lbs. less $\frac{1}{2}$ lb., and on C of 4 lbs. less 1 lb., or $3\frac{1}{2}$ lbs. on B and 3 lbs. on C. And the pressure on B being greater than that on C, the water is forced out at the lower end.

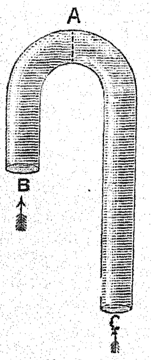

Fig. 46.

Fill any V-shaped tube having one leg longer than the other. Place the fingers over the ends. Dip the short end into a vessel of water, and let the long end hang outside: the water will be taken from the basin in a continuous stream so long as the mouth of the short tube is below the surface of the water; or, if the water be received in another vessel, until the surface of the water in both vessels occupies the same level.

Any bent tube having one leg longer than the other is called a *siphon*.

III. Use of the siphon.

Used by brewers and wine and spirit merchants for emptying casks too heavy to be lifted.

Can be used for carrying water any distance from a higher to a lower level, passing over any elevations not higher than

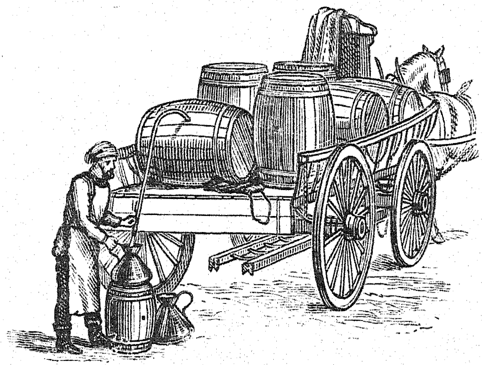

Fig 47.

the length of a column of water which the atmosphere will sustain. What height is this?

The teacher may also suggest other uses of the siphon, such as taking the clear parts of a liquid from the thicker parts, leaving the muddy parts behind; or taking a liquid from beneath the fat which may be floating on the top, leaving the fat behind.

LESSON XVIII.

THE AIR-PUMP.

ARTICLES for illustration :. a diagram, and, if possible, an air-pump.

I. Description.

An air-pump is a machine for extracting the air from closed vessels. Fig. 48 represents a section of one of the more simple forms.

R is the glass "receiver" from which the air has to be exhausted; B is a brass cylinder, called the pump barrel. P is the piston, which is worked by the handle H attached to the rod *r*. C is a brass plate on which the receiver is made

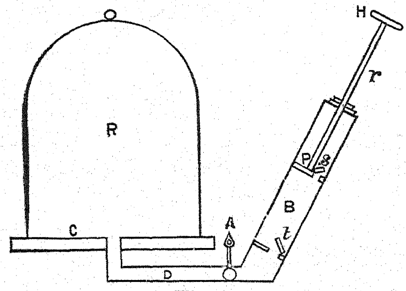

Fig. 48.

to fit very accurately; *s* and *t* are valves opening upwards like small doors. *s* is in the piston itself, and *t* is near the bottom of the barrel. A is a screw which closes the tube D when necessary.

II. Working.

Exp. 125. Suppose the piston to be descending. The valve *t* is closed and the compression of the air in the barrel will open the valve *s* and the enclosed air will escape. Now raise the piston. The pressure of the external air closes the valve *s*, and all the air above the piston will be forced out through the hole in the lid of the barrel through which the rod works. A vacuum would thus be made in the barrel, but the air in the receiver expands, opens the valve *t*, and fills the barrel.

A double stroke of the piston removes a portion of the air remaining in the receiver, because each time a vacuum is made by the piston the air in the receiver expands to fill it. This will go on until the tension of the air in the receiver is too feeble to raise the valve *t*. The receiver will never

become quite empty of air, although what it contains will be exceedingly rarefied.

The air being rarefied, the pressure on the internal surface of the receiver is but little, while at the same time the pressure on the outside is 15 lbs. per square inch. Hence the receiver will be fixed firmly by atmospheric pressure on the brass plate.

The teacher may here explain that the *action* of the lungs and the tubes leading thereto from the mouth in "sucking" the air from a tube is just the action of an air-pump. The lungs are expanded, and the air in the tube *expands* and rushes in. The tongue acts the part of the valve, and stops the mouth of the tube, whilst the air is expelled from the lungs, and the latter expand again.

III. Its uses.

The teacher will tell the children that the air-pump has many uses which will become apparent in future lessons. At present he may exhibit some experiments further illustrating the pressure of the atmosphere.

The following are suggested :—

Exp. 126. Using a glass jar open at both ends as a

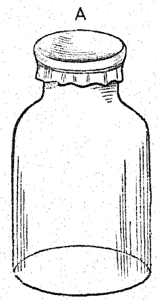

Fig. 49.

receiver (Fig. 49), the open end A may be covered with

sheet india-rubber, or soft bladder. As the air in the receiver is removed the effect of the atmospheric pressure on the bladder or india-rubber is very striking. If the palm of the hand is substituted for the bladder the pressure may be *felt*.

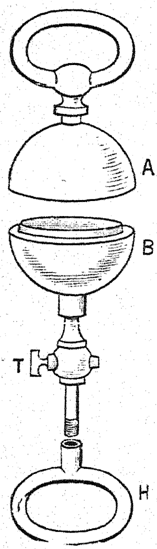

Fig. 50.

Exp. 127. Two hollow half-spheres (Fig. 50) are made exactly to fit one another. One of the half-spheres, B, is screwed on to the plate of the air-pump, the other, A, is then placed firmly* on the top. A receiver is thus formed, which is exhausted by the pump. Turn the tap, T, to shut out the external air and unscrew from the pump. Screw on the handle H, and call upon a couple of scholars to exercise their muscles in trying to separate the half-spheres.

* It is exceedingly difficult to get brass and glass ground so perfectly true as to be air-tight when fitted together. A bit of lard spread over the surfaces will, however, remove all difficulty on that score.

FOURTH STAGE.

FOURTH STAGE.

LESSON I.

EFFECT OF HEAT ON BODIES (1). EXPANSION AND CONTRACTION.

Articles for illustration : bladder, flask, bottle, glass tube, chalk, and nitric or sulphuric acid, thermometer.

I. Gases.

Exp. 128. Half fill a bladder with air or gas, and place in front of the fire. It begins to swell almost at once, and is soon quite full. Why? *Heat expands gases.*

On being removed from the fire the bladder slowly returns to its original size. Why? *Cold contracts gases.* [The teacher should here explain that when we speak of *cold* we mean *absence of heat.*]

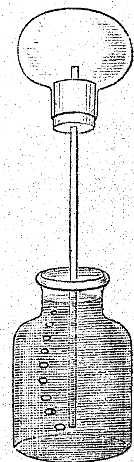

Fig. 51.

Exp. 129. Fill a flask or bottle with carbonic acid gas. Quickly insert cork stopper with tube, as in Fig. 51; invert, and plunge the other end into a bottle nearly full of coloured water. Apply the flame of a spirit-lamp to the flask of gas; or hold the bottle with warm hands. Bubbles will be seen rising in the water from the tube. Why? Because the gas, being expanded by heat, forces its way through the water.

Allow the flask to cool; the water rises in the tube. Why?

Because some of the gas has been forced out, and the remainder is compressed by the pressure of the air outside.

II. Liquids.

Fill a flask quite full of water, and heat it. The water runs over. Why?

Hold the ball of a thermometer in the hand, or breathe on it. The mercury ascends in the tube. Why?

Plunge the bulb in cold water. The column of mercury rapidly shortens. Why?

III. Solids.

Exp. 130. Take a bar of iron which exactly fits into a ring. Heat the bar; it will no longer pass through. Why?

Exp. 131. Or, take two brass tubes, one of which exactly fits into the other. Heat the smaller, it will no longer enter the larger. Why?

Plunge it in cold water. It fits again. Why?

These experiments all show that when we add heat to bodies, whether solid, liquid, or gaseous, the heat makes them expand, and when we withdraw heat from bodies they all contract.

With very slight help from the teacher the children will now be able to explain—

(1) *Why* a kettle should not be quite filled before putting it on the fire to boil.

(2) *Why* a glass often cracks when boiling water is poured into it suddenly.

(3) *Why* the *tire* of a wheel is made a little too small, then made red hot before putting on, and why cold water is then poured on it.

(4) *Why* the iron bolts which are used to fix the iron plates of ships are put in red hot.

(5) *Why* in laying down the iron or steel rails in making a railway the workmen do not fix the ends close together.

(6) *Why* a glass stopper "fixed" in a bottle can readily be removed if we invert the bottle and plunge the neck into hot water.

(7) *Why* chestnuts when being roasted often burst with a loud report and leap for some distance.

(8) *Why* dry wood snaps on being burnt.

(9) *Why* a shrivelled apple, on being roasted, becomes plump again.

LESSON II.

EFFECT OF HEAT ON BODIES (2).—LIQUEFACTION AND VAPORIZATION.

ARTICLES for illustration : any of the following—ice, sulphur, sealing-wax, tin, zinc, lead, glass, iron, mercury, iodine, alcohol, camphor, together with a test-tube and an iron spoon.

I. Liquefaction.

Heat *expands* solids, but it does more. It liquefies nearly all.

The teacher may take any or all of the following solids and *liquefy* or *melt* or *fuse* them :—ice, sulphur, sealing-wax, tin, zinc, lead. The metals may be fused in an iron spoon.

With sufficient heat nearly all bodies can be melted. Some bodies, such as iron, glass, sealing-wax, &c., soften before melting. The teacher may show how we take advantage of this circumstance in the case of iron to fashion various articles by hammering ; and in the case of sealing-wax by making an impression in the wax by means of a seal.

II. Vaporization.

Exp. 132. Heat applied to ice changes it to water. Heat applied to water changes it to a gas or vapour, which we call steam. The process is called *vaporization*. Many solids may be changed to vapour. In addition to water the teacher may vaporize any or all of the following :—sulphur, mer-

cury, alcohol, iodine, camphor, and zinc. The vapour of iodine has a very characteristic colour when seen in a flask. The vapour of zinc burns with a bright green flame.

The teacher will now lead the children to see that the state in which any matter exists, whether in solid, liquid, or vapour, depends entirely on heat.

Further illustrations may also be given. Thus :—

Palm oil is really a liquid oil in Africa (whence it comes). In our country it has the consistency of butter.

Butter is almost a liquid oil in the hottest summer weather in this country. In winter it is quite hard.

Olive oil, again, is a clear liquid in summer; in winter it is solid.

Mercury is a liquid in England. In the coldest regions, in winter it becomes solid. Like water, it is said to be *frozen.*

Ether is ordinarily a liquid, but under a summer's sun it boils, and becomes a gas or vapour.

We may say generally that—

Heat added to a solid gives a liquid.

Heat added to a liquid gives a vapour

Heat subtracted from a gas gives a liquid.

Heat subtracted from a liquid gives a solid.

LESSON III.

THE THERMOMETER.

ARTICLES for illustration: mercury, tube with very narrow bore, and a Fahrenheit's thermometer.

I. Our senses are not exact measures of heat.

Exp. 133. Take three basins; in one basin put water at about 50° and in another water at about 90°. Direct a scholar to place one hand in the water in one basin and the other in the water in the other basin for a few seconds.

Now pour both waters into the third basin, and let the scholar put both hands into the mixture. To one hand the water will seem warm, to the other it will feel cold. This shows that our sense of feeling is not a correct measure of heat.

Again, the atmosphere at say 50° will feel cold to a person coming from a warm room; but to a person emerging from an ice-house it will seem warm. Or again, marble, wood, and flannel may all be of the same temperature; but to the hand the wood will feel colder than the flannel, and the marble will seem colder than the wood.

II. How we measure heat.

The *amount* of expansion which bodies undergo under varying temperatures is the best measure of heat. But we must select a substance which undergoes considerable expansion, and which is not easily changed into another state by either heat or cold. Solids would not be suitable. Why? They undergo too little expansion to be easily seen. Gases are not convenient. Why? They are affected too much by atmospheric pressure, which is constantly changing.

We select liquids. Will water answer well? Why not? It changes to solid ice at a temperature not very low, and to steam at a temperature not very high. Spirits of wine answers well for very low temperatures, but changes to vapour at a lower temperature than water. Mercury is not easily frozen, and does not change to vapour till a high temperature is reached, and is therefore the substance best suited for measuring expansion, and thereby the amount of heat.

III. The mercurial thermometer.

Take a *capillary* tube open at one end but with a bulb blown at the other.

Exp. 134. *To fill the tube.* Heat the bulb. The air

expands and part of it is expelled. Plunge the open end at once into mercury. As the air cools the pressure of the atmosphere without forces some of the mercury* up the tube into the bulb.

Next heat the mercury in the bulb until it boils, when its vapour will drive out all the air and fill the tube. Plunge the open end again into mercury. The bulb and tube will now be filled with mercury. Why?

Seal the open end, by melting the glass, before the mercury has time to cool.

To graduate the thermometer, viz. to mark the *steps* or *degrees* of heat. Put the thermometer in a vessel containing melting ice. The column of mercury falls because heat is withdrawn. When the column becomes stationary mark with a file on the tube the position of the top of the column of mercury. This point we call the *melting point* of ice, or, which is the same thing, the *freezing point* of water (Fig. 52).

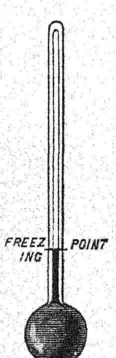

Fig. 52.

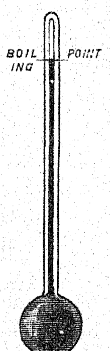

Fig. 53.

Next, suspend the instrument in steam rising from *boiling* water. The column rises because the heat expands the mercury. When it again becomes stationary mark the position of the top of the column. This point is called the *boiling point* of water (Fig. 53).

We have now fixed two points on the tube corresponding to the *boiling* and *freezing* points of water respectively. Our next business is to divide the space between these two points into *steps*, or *grades*. In one thermometer the freezing point is marked 0 and the boiling point 100, and the space is divided therefore into 100 steps. This thermometer is called the Centigrade, viz. having *a hundred steps.*

* We cannot *pour* mercury into a capillary tube.

The thermometer most commonly used for household purposes in our country is called after its first maker, Fahrenheit. On this thermometer the freezing point is marked 32 and the boiling point 212. Thus the space between is divided into 180 parts or *degrees*. Other degrees are marked (if necessary) above 212 and below 32. The cipher (or zero) on Fahrenheit's thermometer was erroneously supposed to represent the lowest temperature attainable. It is about the temperature resulting from the melting of a mixture of snow, or crushed ice and salt.

The teacher may show how the marks are made on the tube. It is coated with wax, and then scratches are made in the wax with the point of a needle. The tube is then placed in a solution (hydrofluoric acid) which eats into the glass, but does not affect the wax.

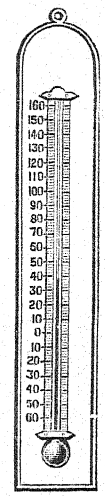

Fig. 54.
CENTIGRADE THERMOMETER.

He may also show how to find the temperature on one scale that corresponds to a given temperature on the other.

$$\begin{aligned} 180^\circ \text{ Fahr.} &= 100^\circ \text{ Cent.} \\ 9^\circ \quad ,, &= 5^\circ \quad ,, \\ 1^\circ \quad ,, &= \tfrac{5}{9}^\circ \quad ,, \\ \text{And } 1^\circ \text{ Cent.} &= \tfrac{9}{5}^\circ \text{ Fahr.} \end{aligned}$$

We must remember, however, that the number which represents a certain temperature on Fahrenheit's scale does not, as on a Centigrade scale, represent the number of degrees above freezing. It is 32° too many.

Hence in changing from Fahr. to Cent. *subtract* 32 *from the given number and multiply by* $\frac{5}{9}$. And to change from Cent. to Fahr. *multiply the given number by* $\frac{9}{5}$ *and add* 32.

The degrees are usually marked on the "frame" in which the tube and bulb are fixed (Fig. 54).

LESSON IV.

FREEZING OF WATER.

ARTICLES for illustration : *if possible* a thermometer tube, and a freezing mixture ; a thermometer.

The teacher will elicit from the children the following *general laws* given in preceding lessons.

1. Bodies expand as they receive heat. That is, the molecules get farther apart, and the bodies become *less dense.*

2. Bodies contract as heat is subtracted. That is, the molecules get closer together, and the bodies become *more dense.*

3. That a denser body has more weight than an equal bulk of a less dense body.

From this the children may be led to see—

1. That as water in lakes, and ponds, and streams cools first near the surface, the particles become more dense and sink to the bottom, forcing up the less dense, because warmer, particles from below. In this way the whole body of water becomes cooled.

2. That without some change, or deviation, or special exception, from the general law that *bodies contract on the removal of heat,* the process of cooling under a cold atmosphere would go on until the entire mass got just below 32°, when the whole would be changed to ice.

3. That in frosty weather this would change all the water of our ponds, and streams, and shallow lakes to solid ice, killing the fish, and many other of its inhabitants, and making it probable that the heat of summer would scarcely be sufficient to re-convert the whole of the ice to water.

The teacher may now tell the children of the wonderful exception to the general law in the case of water. Water contracts and becomes heavier, bulk for bulk, on cooling, till it reaches about 40° Fah., that is about 8° above freezing

point, and then as it still further cools it expands till it gets below 32°, when it changes to ice.* A pint of water at 40° becomes $1\frac{1}{11}$ pints of ice at 32°.

The contraction and expansion of water in cooling from say 50° or 60° to 32° may be shown by using water instead of mercury in a thermometer tube, and placing the bulb and tube in a freezing mixture of ice and salt.

Thus it is that ice always forms at the surface of water, and there remains as a kind of coating to keep off the cold winds from the water below.

With a little help the children will now be able to explain—

1. *Why* a bottle filled with water and tightly corked will burst if placed in a freezing mixture.
2. *Why* water-pipes frequently burst during frosty weather.†
3. *Why* rocks and stones often split in winter.
4. *How* frosts pulverize the soil.
5. *Why* shallow water freezes over very quickly in frosty weather.
6. *Why* lakes of very deep water seldom freeze over, even in severe winters.

LESSON V.

BOILING OF WATER—CONVECTION.

ARTICLES for illustration: Florence flask, narrow tube, aniline solution, large test-tube, small lump of ice, the spirit-lamp.

Refer the children back to the process which goes on during the cooling of water from the surface.

* Sea water does not freeze till cooled 4° or 5° below the freezing point of fresh water.

† Occasion may be taken to correct the common error that the pipes are burst by the thaw.

The cooler particles sink down, the warmer particles rise to the top. Why?

I. Boiling.

The same process goes on when we *boil* water. The particles below are heated; they become, therefore, bulk for bulk, lighter and rise to the surface, and the cooler particles sink down, to be in their turn made warmer and lighter.

After a time some of the water at the bottom becomes changed to steam. The steam rises in bells or bubbles, which burst as they become cooled in the cooler water above.

As heat is still further applied the bells cannot be cooled sufficiently to burst in the water, and so they reach the top, where the steam escapes into the air.

Soon the bells ascend to the surface in increasing numbers, creating more and more disturbance, and making the well-known *appearance* and *noise* of boiling.

II. Convection.

Exp. 135. The appearances above described may be readily demonstrated by boiling water over the flame of a spirit-lamp in a Florence flask. The upward and downward current may be prettily shown by introducing—before applying heat—a little deeply coloured aniline* solution to the bottom of the flask.

This is done by means of a narrow tube used as a pipette. Stop the lower end with the forefinger of the left hand; fill the tube; press the forefinger of the right hand on the upper end; remove the left hand forefinger. The solution is supported in the tube. How?

Thrust the lower end of the tube to the bottom of the flask (Fig. 55) and remove the finger; the solution flows out and colours the water at the bottom.

* A few grains of cochineal thrown into the water will answer the same purpose.

Place the spirit-lamp under the flask, so that the point of the flame may just touch the middle of the bottom. Soon the coloured water immediately over the flame becomes heated and rises as an upward current through the colourless water. At the same time the cooler liquid at the sides begins to descend to take the place of that which rises, and in a short time the descending currents are made manifest to the eye by the colour in the water.

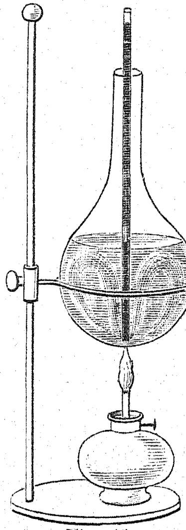

Fig. 55.

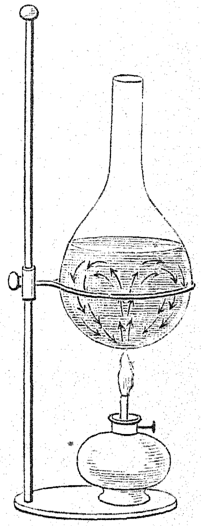

Fig. 56.

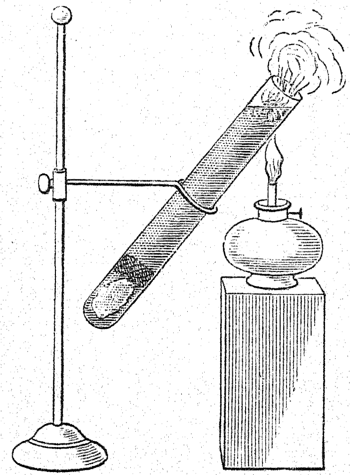

Fig. 57.

In this way heat is conveyed, or *carried*, to all parts of the liquid; and the process is called *convection*, viz. a *carrying of heat*.

III. Water a bad conductor of heat.

Exp. 136. The teacher may now introduce an interesting experiment to show that the water does not carry heated particles downwards as well as upwards. Put a little ice at the bottom of a test-tube and keep it in position by a coil of wire

Nearly fill the tube with cold water, and apply the flame of the spirit lamp at a little distance from the top (see Fig. 57). The water at the top may be made to boil, while the ice at the bottom remains unmelted. If ice is not to be obtained put a little aniline solution at the bottom.

Why should we apply heat at the bottom of a vessel when we wish to boil water quickly?

Why does the water sometimes boil in the spout of a kettle before the main body in the kettle boils?

LESSON VI.

DISTILLATION.

ARTICLES for illustration: a small retort, Florence flask, lamp and stand.

I. How vapour and steam are condensed. Distillation.

Exp. 137. Place a cold glass over the flame of the spirit-lamp. Some of the vapour produced in burning condenses as water on the cold glass.

Breathe on a piece of cold slate. The vapour from the breath condenses as water on the cold slate.

Exp. 138. Heat water in a retort, arranged as in Fig. 58. The steam passes down the long neck into a Florence flask, the latter standing in a basin of cold water. The heat from the spirit-lamp changes the water into steam, and the cold water in the basin changes the steam back again to water. This process is called *distillation*.

If ink be placed in the retort instead of clear water, it will be found that only *pure water* is distilled over. The other ingredients of the ink are left behind in the retort. Now put brine or a solution of sugar in the retort and distil. Again only *pure water* distils over, the salt or sugar is left behind.

When sea-water evaporates, all the salt is left behind, or the rain-water would be salt to the taste.

Fresh water can be got out of sea-water by distillation, and many large ships now carry apparatus for the purpose.

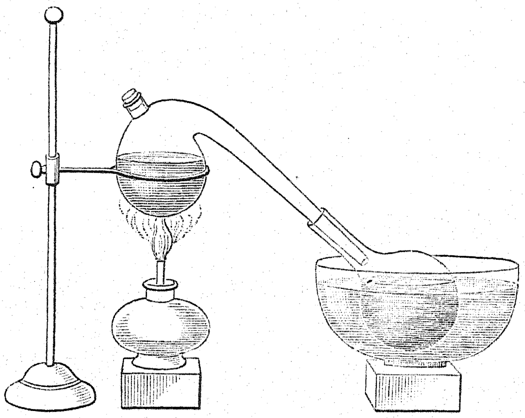

Fig. 58.

Distilled water is the purest form of water, but is not pleasant to drink.

II. The boiling point of liquids varies.

Exp. 139. Heat *spirits of wine* in a Florence flask. When it boils insert a thermometer. It will be found that the top of the mercury stands at about 172°, showing that this liquid boils and changes to vapour at 172°, or about 40° lower than water. *Ether* boils at about 95°. It can be boiled by placing it in the rays of the sun on almost any day in summer. *Mercury* boils at about 660°.

III. Uses of distillation.

Distillation is chiefly employed to get spirits from malt liquor, and brandy from wine. These liquids contain a mixture of alcohol and water. As alcohol distils over at about 172°, arrangements are so made that the mixture shall

not be heated above 180°. At this temperature the spirit distils over, leaving the water behind. As a matter of fact some of the water does distil over with the spirit, and it requires a second distillation to produce proof-spirit, a mixture of half water and half alcohol.

Distillation is also used to separate the more volatile benzoline from the less volatile paraffin oil; and the latter again from the solid paraffin.

LESSON VII.

EFFECT OF PRESSURE ON THE BOILING POINT OF LIQUIDS.

ARTICLES for illustration: Florence flask and spirit-lamp.

I. Diminished pressure lowers, increased pressure raises, the boiling point of liquids.

Exp. 140. Half fill a Florence flask with water. Boil over the spirit-lamp; the steam will drive out and replace all the air in the flask above the water. Remove the lamp. Cork the flask tightly, and invert as shown in Fig. 59. When the boiling ceases let cold water flow from a sponge over the flask, and the water commences to boil again.

Now when the heat has been removed and cold water poured on the flask, the temperature of the water inside must be considerably below the usual boiling point of water, 212°.

The explanation of the second boiling is simple. The space above the water was filled with steam, the application of cold water condensed it, so that the pressure on the water was diminished.

From this we learn that under less pressure than that given by the ordinary atmosphere water boils at a lower

temperature. And the converse of this is true: if we increase the pressure we raise the boiling point.

The same law holds good for all liquids.

Exp. 141. Under the receiver of an air-pump (see page 112), the pressure on the water may be diminished almost to nothing, and water may be made to boil at such temperatures as 70° or 80°, or even lower.

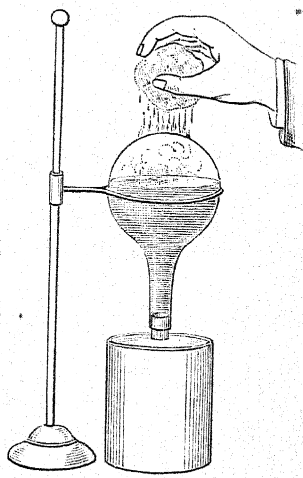

Fig. 59.

The presence of salts in solution raises the boiling point.

The teacher can show this by boiling brine or syrup, placing therein a suitable thermometer* to register the temperature. The boiling point is raised 10 or 12° Fah.

II. Practical applications following on the facts as now demonstrated.

1. In refining sugar, water has to be driven from the syrup by boiling. Now the boiling point of syrup is about 220°, and at this temperature it is apt to get burned and discoloured. To avoid this the syrup is put into closed vessels, from which the air and vapour can be drawn off by a pump. In this way, by removing pressure the syrup is boiled at 150°, and the risk of burning is avoided.

2. In the boiler of a steam-engine the pressure of the steam on the water is very great. If ten times as great as the ordinary pressure of the atmosphere, the boiling point rises to 360° Fah.

3. The pressure of the atmosphere on high mountains, as

* Viz., a thermometer which registers temperatures above 212°.

we have seen, is considerably diminished, and water boils at a lower temperaturo. On the top of Mont Blanc, for instance, water boils at about 160°, and this temperature is not high enough to cook potatoes, or an egg. The potatoes will not get soft, and the egg will not harden.

LESSON VIII.

STEAM AND THE STEAM-ENGINE.

ARTICLES for illustration: diagram of steam-engine.

I. Steam is highly elastic; hence has great expansive force.

The teacher may introduce this lesson by eliciting from the scholars any facts about steam—how it is produced, its chief properties, how it resembles air, and so on.

He should next direct attention to the most important property of steam—its *elasticity* or *expansive force,* the property on which depends its use in the "steam-engine."

The rush of steam from the steam-engine gives some notion of the great expansive force of steam.

If water is boiled in a vessel closed quite tight with a cork or lid, either the cork or lid will be blown out, or the vessel will burst into pieces. Great iron boilers are sometimes burst into thousands of fragments by the expansive power of steam.

Under the ordinary pressure of the atmosphere a cubic foot of water when changed to steam occupies 1,700 cubic feet of space. That is, a cubic foot of water will produce sufficient steam under the ordinary pressure of the atmosphere—15 lbs. to the square inch—to fill as nearly as possible a boiler 12 feet long, 12 feet wide, and 12 feet high.

Suppose the top of the boiler could be so arranged as to work up and down like a square piston in a square box,

then at this volume it would remain stationary; that is, there would be a pressure downwards on the lid equal to 15 lbs. on every square inch, or nearly a ton on each square foot of surface, and there must be also a pressure upwards or expansive force in the steam of exactly the same power. Now if a ton weight be placed on each square foot of the lid the latter will be pressed half-way down the boiler and the volume of the steam will be one-half its former volume, but its expansive force is doubled, as we see from the fact that it supports double the weight.

The same effect of doubling the expansive force is produced if we put double the amount of steam in our boiler. And, generally, we may say that the more steam we can get into a boiler the greater is the pressure or expansive force of the confined gas.

If we heat water in a boiler there is no limit to the expansive force of the steam produced except the strength of the walls of the boiler itself.

II. The steam-engine.

The steam-engine is a machine constructed to utilize the expansive, or elastic force of steam.

The teacher may illustrate the principle of the steam-engine by making sketches (Figs. 60 and 61) on a blackboard. A D is a cylinder in which the piston, P, works up and down, or backwards and forwards, but not quite to the ends of the cylinder; *a* and *c* are tubes communicating with the air, but fitted with stop-cocks; *b* and *d* are tubes communicating with a boiler B. These tubes are also fitted with stop-cocks.

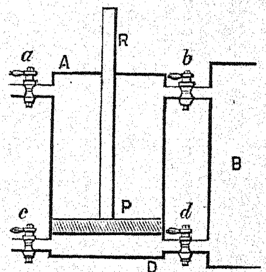

Fig. 60.

Let us suppose all the stop-cocks to be closed, the piston to be at the bottom of the cylinder (Fig. 60), and the boiler

B to be full of compressed steam. Open *a* and *d*. The steam rushes in at *d* and forces the piston to the position it occupies in Fig. 61, the air being forced out at *a*.

Now close *a* and *d* and open *b* and *c*. The greater part of the compressed steam at once rushes out at *c*, and more compressed steam entering at *b*, the piston is pressed back again to the position it occupies in Fig. 60, forcing out the remainder of the steam in the cylinder. If some heavy body be attached to the end of the piston-rod, it will be pulled backwards and forwards as the piston is pushed backwards and forwards by the steam.

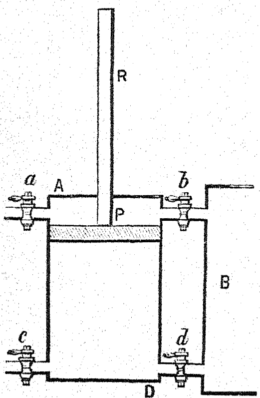

Fig. 61.

This is the essential part of every steam-engine—*the pushing backwards and forwards of a piston in a cylinder by the expansive force of steam.* All the various and intricate parts of a steam-engine are so many mechanical contrivances to make the machine itself to open and shut the entrance and exit pipes, to render the motion uniform and of the kind required, and to utilize as much of the steam-force as possible.

Fig. 62 will serve to illustrate the working of a steam-engine in a very primitive form.

S represents the *steam-pipe* leading from the boiler. It conducts the steam to the *valve-chest*, V C. In this chest the slide-valve V moves to and fro, and opens and closes alternately the pipes M and N leading to the cylinder C. When one passage is open the other is always closed.

In Fig. 62 the tube N is open for the passage of steam into the cylinder from the boiler. The tube M is closed to the steam coming from the boiler, but is open through the interior of the valve V to the air at O.

The expansive force of the steam presses the piston

onwards towards R; motion is given to the crank G, and the shaft A is half rotated.

When the piston is at E (Fig. 63) the valve closes the passage N to the steam-pipe, but forms a passage for exit to the air. At the same time it opens the passage M, to allow

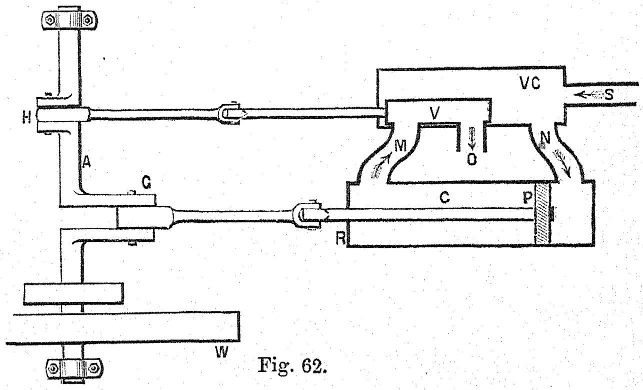

Fig. 62.

the steam to force the piston in the contrary direction The double movement of the piston rod once forward and once backward completes one revolution of the shaft.

This rotation sets the crank H in motion, and by means of a rod the valve V is moved to and fro. The cranks are so arranged that the valve shall move in a direction *contrary* to that of the piston.

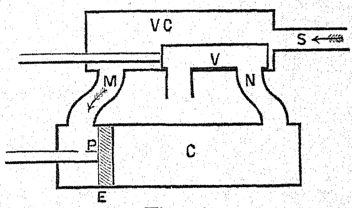

Fig. 63.

W (Fig. 62) is a large and heavy fly-wheel, which serves to keep the motion of the whole regular and uniform. By means of a belt passing over this wheel motion may be communicated to any machinery desirable.

LESSON IX.

CONDUCTION OF HEAT.—CLOTHING.

ARTICLES for illustration: metal wires or rods, glass rod, sealing-wax, and any of the conductors, bad conductors, and non-conductors mentioned below.

We have seen in a previous lesson one method by which heat is carried in liquids, viz. by *convection*; but the molecules of a solid are not free to move, and so cannot carry heat by *convection*.

I. Conduction.

Exp. 142. Take a piece of copper wire four or five inches long, and hold one end in the flame of the spirit-lamp. Soon it gets too hot at the other end to be held in the hand. What does this teach us? *That the heat travels along the wire; but that it occupies a certain time in doing so.*

Exp. 143. Try a glass rod in one hand, and the wire in the other. You can hold the glass rod an inch or two off from the flame even after you have been obliged to drop the wire. What do we learn from this? *We learn that the copper wire conveys or conducts the heat more quickly than the glass.*

Heat, when it travels through bodies in this way, is said to be *conducted.* Those bodies which conduct heat quickly are called *good conductors.* Those which conduct heat slowly are called *bad* conductors. Some conduct so little heat as to be named *non-conductors.*

II. Conductors.

The teacher may now direct the scholars to test the conducting power of various substances, such as other metal wires, mercury in a narrow tube,* water in a test-tube, sealing-wax, wood, stone, earthenware, cork, leather, wool, &c., &c.

* See Fig. 57, page 127.

Arrange in three classes, writing names on the black-board, thus:—

Good Conductors.	Bad Conductors.	Non-Conductors.
silver	stone	wool
copper	brick	fur
gold	earthenware	silk
brass	glass	hair
tin	wood	feathers
iron	sealing-wax	cork
	leather	india-rubber
	linen	air
	cotton	

Special attention should be called to air as a non-conducting body.

III. Special uses of good and bad conductors.

Vessels used for cooking purposes, for melting or boiling, need to be good conductors to let the heat pass through quickly.

Tools used hot, such as soldering-irons, branding-irons, &c., must have non-conducting handles. These are generally made of wood.

Clothing, especially for winter use, should be made of non-conductors, so that the heat of the body may not escape too quickly into the cold air without.

The teacher may now get answers to such questions as the following:—

1. *Why* are fireproof safes made with double walls having the space between filled with sand, or some other bad conductor?

2. *Why* do people wrap ice in flannel, or cover it with sawdust during hot weather?

3. *Why* are windows in cold countries made double?

4. Two substances, say wool and marble, have the *same temperature*, as tested by a thermometer. When they are colder than the hand, *why* does the marble feel *colder* to the touch than the wool? When they are hotter than the hand *why* does the marble feel *hotter* than the wool?

5. *Why* does a stone hearth feel colder than a carpet, or hearthrug?

6. *Why* are woollen or paper pads used for holding the handles of kettles?

7. *Why* are wooden handles fixed to coffee-pots?

8. *Why* are woollen and fur garments worn in cold weather?

LESSON X.

RADIATION OF HEAT.—RADIATORS.

ARTICLES for illustration: rod of iron, three pieces of tin-plate [see below], three tin cans [see below].

I. Radiation.

Exp. 144. Heat a rod of iron—the poker for instance—red hot.

Let children hold their hands near the poker; the heat is felt in *every direction* at some distance from the poker. Or the teacher can show that a match will take fire when brought near without touching the poker.

How does the heat get from the poker to the hand or the match? Not by *conduction*, for air is a bad conductor. And besides, it has been found by experiment that heat passes from one body to another quite as well in a vacuum. Again, heat can pass through bodies not in *contact*. For instance, the heat of the sun passes through our windows and warms our rooms.

We cannot tell for certain *how* the heat passes across from the warmer to the cooler body; but we are quite sure

that, like light, it passes in straight lines, or *rays* as they are usually called. The process of communicating heat from one body to another by *rays* is called *radiation.* The radiated heat which is *taken up* by other bodies is said to be *absorbed.*

In the experiment the heat radiated from the red-hot poker is absorbed by other bodies around, and the process goes on until the poker and the other bodies in the room are of the same temperature.

The teacher may show how heat is radiated from a body by sticking pins or needles into a ball of worsted, taking care that they radiate from the centre of the ball.

II. Good and bad radiators.

Exp. 145. Take three pieces of tin-plate, one bright and clean, another rusty and therefore rough, and paste brown paper over the third, or cover it with lamp-black. Place them out in the sun, or in front of a fire at some distance from it. The rusty and the covered plate will in a few minutes feel hotter than the polished plate. What do we learn from this? *That bodies having dark or rough surfaces absorb heat more quickly than bodies with polished surfaces.*

Exp. 146. Next take three "tin" cans of the same size. Cover one on the outside with brown paper, the second with lamp-black, leaving the third clean and bright. Fill each with warm water of the same temperature, and set them on wool mats, or several thicknesses of brown paper, and at some distance apart, and of course away from the fire. In the course of ten minutes or so test the water with the thermometer. The water in the bright vessel will be hotter than that in either of the others. What does this experiment teach us? *That rough and dark surfaces radiate heat more quickly than bright surfaces.*

And from the two experiments we learn that *good radiators are good absorbers*, and that *bad radiators are bad absorbers.*

Dark clothing absorbs and radiates heat more rapidly than light-coloured clothing. In very cold countries some animals, such as hares and foxes, change their colour in the winter and turn white. The advantage is that the heat of their bodies does not pass away so quickly through a white coat.

Absorption and radiation are going on around us continually. The earth absorbs the heat of the sun's rays during the day, and radiates it at night. As the days in summer are much longer than the nights, there is more time for absorption than for radiation; and as the days in winter are shorter than the summer days, there is less time for absorption in winter than for radiation, and thus absorption and radiation of heat account *in part* for the difference in summer and winter temperatures.

LESSON XI.

HOW HEAT AFFECTS THE ABSORPTION OF WATERY VAPOUR BY THE ATMOSPHERE.

ARTICLES for illustration: alum, water, spirit-lamp.

The children are familiar with the fact that water, in the shape of vapour, is always present in the atmosphere, and that the amount is constantly varying, the pressure or weight of the atmosphere varying with it, as shown by the barometer.

The aim of this lesson will be to show (1) that *the warmer the air the more moisture it can absorb; and* (2) *that the capacity for absorption increases in a greater ratio than the increase of temperature.*

I. The warmer the air, the more moisture it can absorb.

Exp. 147. Dissolve alum in cold water till the water

can hold no more. The water is said to be saturated. Heat the solution to about 120°. It can absorb more alum, but presently becomes saturated again. Heat the water to boiling point. It requires more alum again to make a saturated solution at the boiling point. Now allow the solution to cool. As the water cools some of the alum comes out and falls to the bottom or clings in pretty crystals to any rough surface. On the further cooling more alum comes out, until at freezing point the water holds very much less alum in solution than at higher temperatures.

If we heat a saturated solution of alum at say 60°, to any temperature above 60° and then cool it again, no alum comes out before we arrive again at 60°, when, if we cool still more, a portion of the solid is deposited.

Now air acts with regard to watery vapour in a way very similar to the action of water on alum. At any specified temperature the air can hold any portion of vapour up to a certain amount. When it is quite full and can absorb no more it is said to be *saturated.* If we increase the temperature we enable the air to take up more vapour, but again its power of absorption is limited. The process of absorption stops as soon as the air becomes saturated. It is quite clear, then, that for every degree of temperature the air has a different *point of saturation.*

Just as with the solution of alum, when saturated air becomes cooled some of the water is forced or squeezed out.

II. The capacity for absorption increases in a greater ratio than the increase of temperature.

To make this very clear the teacher should take such an example as the following:—

Suppose we have a cubical box 5 feet in the side. The air in this box at 32° Fahr., will hold about an *ounce* of water in the shape of vapour. That is, an ounce of water-vapour will saturate 125 cubic feet of air at 32° Fahr.

Now if the temperature of the air be raised say 30° Fahr.* the air in the box can hold *double* the amount of moisture, viz. two ounces. Raise another 30°, viz. to 92° Fahr., it can hold double the amount it held at 62° Fahr., that is, it can hold *four ounces*, and so on. *For every 30° of added temperature the capacity for holding water is doubled.* As a matter of fact, however, air is not often saturated.

Given 125 cubic feet of air at 92°, holding two ounces of vapour, we may cool this air down to 62°, that is to the point of saturation with two ounces, before any water will be pressed out. If we cool still further some of the vapour will be given off, and will be seen as dew or fog, or in some other form.

The children may learn from this lesson why water "dries up" or changes to vapour more quickly on a day when the air is dry than when the air is humid or moist; and why it changes to vapour more rapidly, *as a rule*, in summer than in winter. The further the atmosphere is from the point of saturation, and the higher its temperature, the more water-vapour can it absorb.

With a little help the children will now be able to answer such questions as the following:—

1. *Where* may we expect the air to be always nearest to its point of saturation?

2. *Why* are south-west winds in England moist and humid?

3. In what parts of the earth does the atmosphere hold the largest amount of vapour, and *why*?

4. *What* is the cause of the general complaint of the dryness of the air in rooms heated by stoves, or furnaces?

5. *Why* do people often put saucers containing water over stoves?

* Authorities differ somewhat both as to this number and to the amount of vapour which water can hold at 32° Fahr.

LESSON XII.

HEAT THE CAUSE OF MOTION IN THE AIR.

ARTICLES for illustration: glass trough (or substitute), oil, candle.

I. Recapitulation.

The teacher should first elicit from the children the two causes of variation in the weight of any given volume of the atmosphere, viz. *heat* and the *amount of water-vapour present*. Thus a cubic foot of warm air has less weight than a cubic foot of colder air, and a cubic foot of moist air has less weight than a cubic foot of dry air.

Secondly, he should get from the children what must be the result when there is a mass of warm air in one place and cold air in another; or a mass of warm moist air in one place and cold dry air in another; and generally that if there is *lighter* air in one part, and *heavier* in another, the colder air will rush in, and forcing up the lighter air occupy its place.

Exp. 148. He may illustrate as follows: divide a glass trough in the centre with a fitted piece of cork; fill one side with oil and the other with coloured-water and then remove the partition. The heavier water presses up the lighter oil and partly takes its place, the oil at the same time taking up some of the space at first occupied by the water.

There are, in fact, two currents. The heavier water flows one way and the lighter oil the other. *Much in the same way motion in the air is brought about.*

II. Action of stoves and open fires.

In warming a room the cold air is constantly pushing up the warmer air, and the upper part of the room consequently is always warmer than the part near the floor.

The teacher may show the upward current of warm air from a lamp or a stove-pipe by holding in it some light substance, such as a feather.

When there is a fire in the room the air is ever pushing towards it. There is a current of light because hot air going up the chimney, and air is coming in from every point, from every door and window, crack and crevice, to supply the place of that which escapes up the chimney.

Hold a lighted candle near the fireplace; the flame bends towards the fire. Hold it near the bottom of the door and it is blown inwards.

Some of the warm air of the room, too, escapes through any opening near the ceiling, the top of the door for instance. Open, for about an inch, the door, of a room in which the air is considerably warmer than the atmosphere outside, and hold the flame of a candle near the top, it is blown outwards. Now hold it near the bottom, it is blown inwards. *Why*?

In an open fireplace some of the air of the room goes up the chimney *above* and not through the fire; this is colder than the air which goes through the fire, and the current up the chimney therefore is not very rapid. But if you prevent this cooler air from going up by placing a "blower" above the bars of the grate all the air must go through the fire. This makes the air hotter, and the current up the chimney becomes much more rapid.

As we shall learn by and by, the more free is the supply of air to the fire, the more briskly the fire burns. This explains why a blower makes the fire burn more fiercely.

III. Winds.

The *land and sea breezes* will serve to illustrate how heat brings about winds.

These winds blow only in warm regions of the earth and, as their name implies, near the sea. They are caused by

the difference in the absorbing and radiating powers of land and water.

In the evening, after a warm day, the land radiates its heat much more quickly than the water, and the air above the land therefore becomes cooled much more quickly than the air above the water. It follows that the cold air rushes *from* the land to displace the warmer air above the water. In the evening, therefore, the breeze is *from the land.*

In the morning the air over the land becomes warmed quicker than the air over the water, and a breeze *from the sea* sets in.*

LESSON XIII.

DEW AND HOAR-FROST.

I. Formation of Dew.

From what has already been learnt about the radiation and absorption of heat by solids, and the absorption of vapour by the air, the teacher will be able to elicit from the children all the salient points in connection with the formation of *dew.*

He should refer first of all to the formation of water on the outside of a glass of cold water when brought into a warm room, to the formation of water on the windows of our houses, on the windows of closed carriages, and on the walls of our houses when a thaw sets in. The explanation is in all cases the same: the cold objects cool the air close to them till the point of saturation is reached, and then on further cooling some of the vapour is deposited on the cold body.

We have seen that *air absorbs and radiates heat very slowly.* But many of the objects on the surface of the earth *absorb and radiate very quickly.*

* It is a matter for the discretion of the teacher whether or not to pursu this subject further at this stage.

On warm sunny days the earth and all the objects on its surface absorb heat. But when the cool evening comes this heat is radiated into the air, and the warmed air rises and cooler air from above takes its place. This goes on until the air in contact with the now cold bodies gets cooled so far that it fails to retain all the moisture which it held when warmer, and the moisture—squeezed out as it were—is *formed* on the cool bodies in little drops, which we call *dew.*

II. How the formation of dew is promoted or retarded.

This is the general explanation of the formation of dew; but many circumstances assist or retard its formation, which it will be interesting to note.

1. Dew is formed most abundantly when a fine, clear, cool night follows a hot sunny day. [Such days are most common in autumn.] On a clear cool night the earth radiates its heat very freely.

2. Little or no dew is formed on a cloudy or windy night. Clouds radiate heat back again and prevent its going into the cold atmosphere above. Winds keep the air mixed so that the lower stratum is not kept near the earth sufficiently long to be cooled below its point of saturation.

3. Dew is deposited freely on grass, or on wool, or mats; while little or none is deposited on stones, or on the gravel-walk. Grass and wool absorb, and hence radiate heat more freely than the stones and gravel.

4. Dew is never deposited under cover. The deposit of dew under trees is very slight. The covering above radiates the heat back again.

5. When the air is brought into contact with bodies cooled below 32° Fahr., the moisture as it forms on the cold bodies becomes frozen, and *hoar-frost* is the result.

6. A very slight covering—even paper or muslin—serves to protect shrubs and plants from frost by preventing or retarding the radiation of heat from the plant.

7. When the air is very full of moisture, and the night has been very calm and the radiation consequently very abundant, the chill is so rapid that the vapour is condensed more quickly than it can be deposited, and a *mist* or *fog* is formed. This mist prevents any further radiation of heat from the earth.

LESSON XIV.

RAIN, SNOW, HAIL, SLEET.

I. How rain is formed.

The teacher will refer to Lesson VIII. of this stage for the general law on which the formation of rain depends, viz. *that the capacity of air for moisture increases or decreases in a greater ratio than the temperature.*

Suppose we have three cubical boxes of air each 5 feet in the side, and therefore containing each 125 cubic feet of air. We will further suppose that the air in each is *saturated* with moisture, the first at a temperature of 32° Fahr., the second at 62°, and the third at 92°.

If the air at 32° contains an ounce of water-vapour, then the air at 62° contains *two ounces* and the air at 92° contains *four ounces.* That is, in the three boxes of air, containing in all 375 cubic feet, there are *seven ounces* of water.

Let us agree to mix the air in these three boxes. Then we shall have 375 cubic feet of air at 62° [because 62° is the average of 32°, 62°, and 92°.]

How much water will 375 cubic feet of air contain at 62°? Clearly *six ounces,* because 125 cubic feet can hold only two ounces.

But we have seen that, before the three boxes are mixed, they contain together *seven ounces,* hence when mixed they give

up *one ounce*. This *one ounce* is squeezed out, because there is no room for it, and it becomes first a mist and then rain.

It must not be supposed that air is always saturated with water-vapour. This is far from being the case, or rain would be constantly falling at every slight change of temperature. But air at varying temperatures and holding varying amounts of water-vapour is being constantly mixed by winds, and whenever the mixture becomes cooled below its point of saturation, the excess forms mists (clouds); on further cooling the tiny particles of mist join together and form rain. But if the mist becomes cooled below 32° Fahr., then it is frozen into *snow*.

II. Questions on interesting facts connected with the formation of rain.

1. *Why does rain fall in drops?* Because the particles attract each other, and those that are near combine and form drops.

2. *How is it that the cold night does not always cause rain?* Because the air is not always near saturation, and it can thus be chilled, and yet hold its vapour.

3. *What is snow?* Condensed vapour frozen by contact with air below 32°.

4. *What is hail?* Hail is rain frozen by passing through a stratum of air below 32° Fahr. in its descent.

5. *How is sleet formed?* Sleet is formed when snow in its descent passes through a bed of air above 32° Fahr. The snow is partially thawed and falls in a half-melted state.

6 *Why is there no snow in summer time?* Snow is formed in the upper regions of the atmosphere as well in summer as in winter, but in summer it becomes melted in its descent through warm air. When rain falls in the valleys in Switzerland in summer, the tops and sides of the mountains often receive a coating of snow.

LESSON XV.

SPECIFIC HEAT.

ARTICLES for illustration: 4-oz. pieces of lead and iron, 4 ozs. of mercury, a small tin vessel, a thermometer, and some apparatus for boiling water.

I. What is specific heat?

Exp. 149. Take equal weights, say 4 ozs., of lead, iron, and mercury, and heat them for some time in boiling water. [The mercury may be held in a test-tube.]

The three metals will have their temperatures raised to 212°. Next take three vessels, each containing say 4 ozs. of water at the ordinary temperature of the room, say 55°, and transfer the metals to these vessels. Each of the solids will, of course, raise the temperature of the water; but they will not raise it equally. The lead will raise it least, the mercury will raise it a little higher than the lead, and the iron considerably more than either.

We may now add 4 ozs. of water at 212° to 4 ozs. at 55°, and we shall find that the hot water raises the temperature of the cold far more even than the iron.

What do we learn from this experiment?

We learn that *some bodies can hold more heat than others.* The iron evidently retained more of the heat got from the boiling water than the lead, for it gave more to the cold water.

If lead takes up less heat than the iron, we should expect that it will take *less time* to reach a certain temperature than iron. And this is so.

Exp. 150. Take the lead first; put it in a tin vessel and hold it over boiling water till it reaches a temperature of say 180°. [To test the temperature, keep the bulb of a thermometer touching it.] Note the time. Now test the iron

in the same way and note the time. As the iron requires more heat to raise it to 180°, it takes considerably more time.

The teacher may also test the converse by noting the time it takes each metal to cool. The lead holding less heat cools first.

Exp. 151. We can show that some bodies hold more heat than others in another way.

Take an ounce of water at 112°, and an ounce at 40°, we get two ounces at 76°, as may be shown by the thermometer.

Now take an ounce of mercury at 112° and an ounce of water at 40°; we have a mixture of two ounces, but the temperature will be only about 42°. The hot water raised the cold through 36°, while the hot mercury raised it only about 2°.

Bodies, then, differ in their power of taking in and holding heat, and the amount of heat which a given weight of a body takes in to raise through a given range of temperature is called the *specific* heat of the body. A *pound weight*, and *one degree* are taken as the units.

II. The importance of water having a high specific heat.

The ocean covers four-fifths of the earth's surface, in some places to the depth of several miles, and this forms an enormous storehouse of heat. It takes up an immense quantity of heat without rising much in temperature, and yields it up again when required, without itself being lowered much in temperature.

The great specific heat of water is therefore the chief agent in *equalizing* the temperature of the globe.

LESSON XVI.

LATENT HEAT.

ARTICLES for illustration: Florence-flask, spirit-lamp, lumps of ice, thermometer.

I. What is latent heat?

Exp. 152. Take a Florence flask, half fill with water, and heat to boiling point over the spirit-lamp. Note the rise of temperature by setting a thermometer in the flask. The mercury rises steadily in the column till it stands at 212°. At this point it is stationary, and no amount of heat further applied under the ordinary pressure of the atmosphere will make the water rise above 212°.

What then becomes of the heat we continue to apply during the boiling of water? We answer this question by asking another. What change does the continued application of heat to water at 212° bring about? Clearly the change in the *state* of water from liquid to gas. *The heat, then, is used up in the process of changing water from the liquid to the gaseous state.* But the steam is no hotter than the water. The heat seems to disappear; at any rate it has no effect on the thermometer, and hence we call it *hidden*, or *latent* heat.

Exp. 153. Now half fill a vessel with cold water, and put in a few lumps of ice. With a thermometer again note the change of temperature. The column of mercury sinks gradually to 32°, where it remains until all the ice is melted. *Even on the application of heat,* the water shows no increase of temperature until the ice has disappeared.

If ice or snow at, say 20°, be placed over a fire, the thermometer will show an increase of temperature till the mercury reaches 32°, but there it will stand so long as ice

or snow remains; but when all the snow and ice are melted, the temperature gradually rises till it reaches 212°.

Here, again, much heat is consumed in the process of changing water from the solid to the liquid state, and the heat used up does not affect the thermometer. It is hidden away or made *latent*.

II. Latent heat of water.

The teacher can next give the children an idea of how much heat is used up, or made latent, in changing ice to water, and water to steam.

Exp. 154. Mix an ounce of water at 32° with an ounce at 174°, and we have two ounces of water at 103°; but mix an ounce of pounded ice at 32° with an ounce of water at 174°, and we get two ounces of water at 32°; that is, no less than 142° of heat have been taken from the ounce of water to melt the ice. Of course, a body in falling through 142° of temperature must *give out* just as much heat as it *takes in* in rising through 142° of temperature.

We may say, then, that the amount of heat required to melt a pound of ice is equal to that required to raise a pound of water through 142°, or equal to that required to raise 142 lbs. of water through 1°.

Thus the *latent heat of water* is said to be 142°.

III. Latent heat of steam.

The children will have noticed, probably, how much longer it takes water to "boil away," viz. change to steam, than it does to raise it to the boiling point from zero—about *five times* as long. The teacher may show this fact by experiment; but an experiment to show the absolute amount of heat made latent in the change of water to steam will probably have to be *described*.

An ounce of steam at 212°—in other words, an ounce of water changed to steam—if passed into 298 ounces of cold

water will raise its temperature 1°. That is, the latent heat of steam is 298°. In this case we have recovered the heat which was latent.

Different bodies vary very much in the amount of heat they make latent on passing from solid to liquid, or liquid to gas. Thus the latent heat of alcohol is less than one-half that of water, while that of ether is less than one-sixth.

IV. The advantages we derive from the high latent heat of water and steam.

1. It takes a considerable quantity of heat to melt ice, and hence it takes a considerable time to complete the change.

If it were not so the winter ice and the snow of the mountains and high valleys would melt too quickly, producing overwhelming torrents and floods.

2. Similarly in the case of steam, if it were generated too quickly, we should be much more liable to dangerous explosions.

The teacher may with advantage still further enlarge on the special properties of water as tending to prevent *sudden changes of temperature.*

LESSON XVII.

COOLING BODIES AND FREEZING MIXTURES.

ARTICLES for illustration: small quantity of ether, snow or ice, ammonium nitrate and chloride, and thermometer.

This lesson consists of interesting applications of principles enunciated in former lessons; and, given the facts as shown by experiment, the reasons may be elicited by questioning.

I. Cooling bodies.

Exp. 155. Pour a little ether on the palm of the hand;

it quickly evaporates and produces a painful sensation of cold.*

"In what *state* was the ether when I poured it into Tom's hand?" *In a liquid state.*

"In what state is it now it has gone away into the air?" *In the state of vapour.*

"To change a liquid to a gas or vapour, what is necessary?" *Heat.*

"Where does the liquid ether obtain its heat?" *From the hand.*

"Then what makes the hand feel cold?" *The heat is taken away to change the liquid ether to vapour of ether.*

On this experiment the teacher may deal with the following:—

1. *Why* we put aromatic vinegar and water on the head when it feels hot and feverish.
2. *How* perspiration cools the body.
3. *Why* ladies use fans in hot rooms.
4. *Why* a windy day *feels* colder than a still one when the temperature, as shown by the thermometer, is the same.
5. *How* a shower of rain cools the atmosphere.
6. *Why* sprinkling a floor with water cools a room.

II. Freezing mixtures.

Exp. 156. Make a mixture of three-parts by weight of snow or pounded ice, and one part of crushed common salt. The two solids liquefy, and if a small bottle of water is placed in the mixture the water will become frozen, even if the mixture is placed in front of the fire.† If tested with the thermometer the temperature will be found many degrees below freezing point.

* Put a drop or two of water on half an ounce of carbon disulphide in a shallow vessel. Place in current of air. The water changes to ice.

† Make a mixture of two parts by weight of pulverised ammonium nitrate and one part of ammonium chloride, and dissolve in three parts of water. Stir the mixture with a test-tube containing a little water. The water in the test-tube will be frozen.

"In what *state* were the snow and salt before mixing?" *In the solid state.*

"What change was brought about on mixing?" *They were changed to a liquid.*

"What was necessary to produce the change?" *Heat.*

"Whence could the bodies obtain their heat?" *Only from themselves and the vessel in which placed.*

"How can you show that the heat was abstracted from the bodies themselves?" *Because they became much colder.*

"If you put your finger first in the freezing mixture and then into some snow at about 32°, which will feel the warmer, and why?" *The snow, because none of its heat has been taken away.*

On this experiment the teacher may ask:—

1. *Why* people should not throw salt on the pavement in frosty weather to melt the snow or ice.

2. *Why* the air often feels cold and chilly when a thaw sets in.

3. *Why* the temperature often rises after a fall of snow.

LESSON XVIII.

SPECIFIC GRAVITY OF SOLIDS.

ARTICLES for illustration: balance, and specimens of same size for weighing, a short tube of lead with solid cylinder to fit exactly, or an equivalent.

The teacher will refer to the lessons on gravity and buoyancy of liquids as an introduction to this lesson, and then tell the class that it is very convenient for us to be able to compare the weights of equal volumes of different bodies.

I. Standard of comparison.

To be able to compare the weights of bodies we must make some *one* body the *standard* for comparison.

Take pieces of, say, wood, cork, and lead of equal bulk, and ask the children to compare their weights. They will say at once that lead is heavier than wood, and wood than cork, but *how much* heavier they cannot say.

Distilled water at a temperature of 39°* is the standard of comparison used in this country.

II. How to compare the weight of any solid with the weigh tof an equal bulk of water.

To show this roughly, but, at the same time, very clearly, the teacher must arrange to measure a bulk of water equal to the bulk of the solid selected for experiment.

For instance, a half inch lead tube two or three inches long, firmly closed at one end with a piece of hard wood. A solid cylinder of lead to fill this tube exactly may be made by pouring in molten lead, or a small earthenware vessel may be filled with melted sealing wax, or a solid glass rod may be found to fit with tolerable exactness into a glass tube.

Example 163. Suppose we take lead for the experiment.

Drop the solid cylinder of lead by means of a piece of thread gently down into a tumbler filled with water to the brim, and collect the displaced water which runs over into a vessel below.

Pour the collected water into the lead tube; it very nearly fills it. It would quite fill it were it not that we lost some on the outside of the tumbler and on the basin below. Now weigh this water. Say it weighs 1 oz.

Now weigh the lead, first in the ordinary way. It will weigh a little over 11 ozs. Now weigh it in water. It weighs a little over 10 ozs. That is, it loses a weight of 1 oz., *or the weight of the water displaced.*

[For method of weighing in water (see Fig. 63). A is a weight equal to the scale-pan which has been removed.]

* At this temperature water is at its maximum density; that is, it is heavier at this temperature than at any other.

From these experiments we learn—

1. That when placed in water a solid displaces a volume of water equal to its own volume.

2. That a solid loses weight when weighed in water.

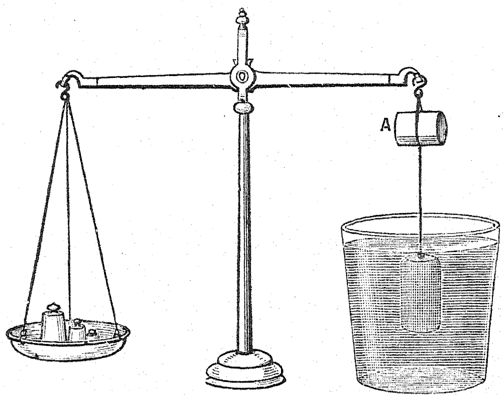

Fig. 64.

3. That the weight of water displaced is equal to the difference between the weight of the solid in air and in water.

In the case of the lead the weight of the lead in air was a little over 11 ozs., and the weight of a volume of water equal to that of the lead was 1 oz. Clearly therefore lead is a little over eleven times the weight of water. And this is called *its own weight compared with water, or its specific gravity.*

If glass had been used instead of lead, we should have found its specific gravity to be $2\frac{1}{2}$. That is, glass is two and a half times as heavy as water. Platinum, the heaviest of metals, is twenty-two times, and gold nineteen times, as heavy as water. Hard oak is a little heavier than water, the other common English hard woods a little lighter than water. Cork has a specific gravity of $\frac{1}{4}$.

If the children are sufficiently advanced the teacher may from the above experiments deduce the rule for finding the specific gravity of solids heavier than water. *Divide the weight in air by the* LOSS *of weight in water. The quotient is the specific gravity.*

SUPPLEMENTARY LESSONS ON PROPORTION.

In Stage V. many of the lessons, especially those on machines, require a clear understanding of *proportion*.

If the Stage coincides with Standard VI., as is most likely, it may be desirable to *rationalise* the proportion that comes under the head of arithmetic.

A sense of proportion is also one of the most important developments of human faculty. Morals (science of what is *due*) depend largely on it. Æsthetics are scarcely anything else than a fine sense of proportion, *e.g.*, in architecture, music, &c. The comfort of social life depends on "give and take," and this is taught only by an inherent sense of proportion.

For these reasons the subject ought to have a more prominent place in school teaching. And as in its most elementary form proportion appeals to the eye and to other senses, its apprehension may be greatly assisted by object lessons.

LESSON I.

ARTICLES for illustration: Two shades of red and two shades of blue colours; blocks of wood, or substitute, weighing respectively 6 lbs., 3 lbs., 2 lbs., and 1 lb.

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1. Comparison of Colours.

Set before the class two patches of some colour—red, for instance—one light and one dark. Mark them A and B.

"What colour is the piece marked A?" *Red.* "And the piece marked B?" *Red.*

"Do you see any difference in the shade of colour in the two pieces?" *Yes, that marked* B *is darker than the one marked* A.

Next take two shades of another colour, say blue, and mark them C and D.

"What difference do you note in these two colours which I have marked C and D?" D *is darker than* C.

"Well, now can you tell me how much darker B is than A, or D than C?" *No.*

"No, because you have no means of exactly measuring colours."

"Can you tell me whether D is as much darker than C as B is darker than A? No, and for the same reason—you have no means of exactly measuring colours. If you could say that B was *twice* as dark as A, and that D was *twice* as dark as C, then you could answer, Yes, D is as much darker than C as B is darker than A."

"We will now take another sort of comparison which you *can* measure."

II. Comparison of Weight.

Take four blocks of wood, weighing respectively 6 lbs., 3 lbs., 2 lbs. and 1 lb. [Of course, weights of any more convenient substances may be substituted.]

Direct a boy to compare as best he can, by holding in his hand, the weights of the larger pieces, and then of the smaller pieces. Now weigh the blocks, and lead the children to compare their weights. Thus, the weight of the first block is *twice* the weight of the second, and the weight of the third block is *twice* the weight of the fourth.

III. Ratio.

"What difference or *relation* is there between the first

block and the second as to their weights?" *The first is twice (or 2 times) the second.*

"The number 2 then represents the *relation* between 6 lbs. and 3 lbs., and we call 2 the *ratio* of 6 lbs. to 3 lbs."

"Now what is the *ratio* of 2 lbs. to 1 lb.? Clearly 2, because the first is *twice* the second. That is, the ratio of 6 lbs. to 3 lbs. is equal to the ratio of 2 lbs. to 1 lb.

The teacher may now explain (1) that to find the ratio of two numbers we always divide the first number by the second. The quotient is the *ratio*. (2) That relation can exist only between things of the same kind. There can be no ratio between lbs. and feet, or between cats and shillings.*

Questions such as the following will fix these ideas in the minds of the scholars.

1. What ratio is there between—

(1)	12 lbs. and 6 lbs.?	*Ans.* 2
(2)	6 lbs. and 12 lbs.?	,, $\frac{1}{2}$
(3)	3d. and 9d.?	,, $\frac{1}{3}$
(4)	8d. and 2d.?	,, 4
(5)	£10 and £1?	,, 10
(6)	£2 and £9?	,, $\frac{2}{9}$

2. What is the ratio of—

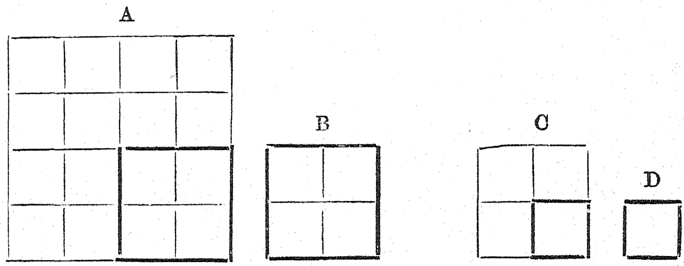
(1)	5 pks. to 2 pks.	*Ans.* 2
(2)	19 yds. to 57 yds.	,, $\frac{1}{3}$
(3)	21 horses to 7 horses	,, 3
(4)	16 feet to 5 feet	,, $3\frac{1}{5}$
(5)	$\frac{1}{2}$ inch to $\frac{1}{4}$ inch	,, 2
(6)	3 cows to £5	,, Impossible.

* See note, page 162.

LESSON II.

I. Further Illustrations of ratio.

Draw squares on the blackboard, the first, A, 2 feet in the side, and divide it into 6-inch squares; the second, B, and



the third, C, each 1 foot in the side, and divide into 6-inch squares; and the third a square 6 inches in the side.

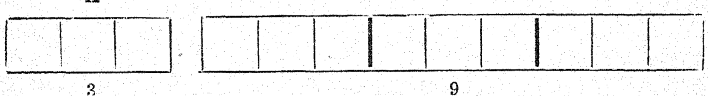
The scholars will see at a glance that the square A is *four* times the area of the square B; and also that the square C is *four* times the area of the square D.

That is, the ratio of A to B is 4, and the ratio of C to D is 4.

In other words, we may say that the ratio of A to B is the *same* as the ratio of C to D, or there is an *equality* of ratios.

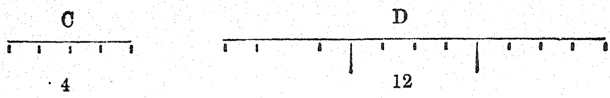
Take another example.

Draw *three* equal squares, and then nine of same size arranging them as in Figs. A and B.



In this example clearly the ratio of A to B is $\frac{3}{9}$ or $\frac{1}{3}$.

Now draw two lines and divide as in C and D.



In the second example the ratio of C to D is $\frac{4}{12}$ or $\frac{1}{3}$.

That is, the ratios in each case are the same. Here is again an *equality of ratios.*

II. Proportion.

Now, when there is equality of ratios, the numbers which represent area, or weight, or length, or anything else, are said to be in *proportion.*

If 10 men can dig 15 acres in a certain time, 5 men, working at the same rate will dig $7\frac{1}{2}$ acres in the same time; the quantities of work done are in *proportion* to the number of men employed.

The ratio of 15 acres and $7\frac{1}{2}$ acres is 2, and the ratio of 10 men and 5 men is 2.

This may be written—

15 acres is to $7\frac{1}{2}$ acres as 10 men is to 5 men.

Or in short—

$$\overset{\text{Acres}}{15} : \overset{\text{Acres}}{7\tfrac{1}{2}} :: \overset{\text{Men}}{10} : \overset{\text{Men}}{5}$$

Again, if 7 men earn £3 3s. (viz. 9s. each) in a given time, 6 men should earn £2 14s. (viz. 9s. each) in the same time.

The ratio of 63s. to 54s. is $\frac{63}{54} = \frac{7}{6}$, and the ratio of 7 men to 6 men is $\frac{7}{6}$.

$$\text{or } \overset{\text{s.}}{63} : \overset{\text{s.}}{54} :: \overset{\text{Men}}{7} : \overset{\text{Men}}{6}$$

Now suppose the 6 men receive only £1 7s. (or 4s. 6d. each) for their work, this would be unfair, it would be *out of proportion;* work and pay should be on the same proportion.

The teacher may show this as follows :—

The ratio of 63s. to 27s. is $\frac{7}{3}$ or $2\frac{1}{3}$, and the ratio of 7 men to 6 men is $\frac{7}{6}$ or $1\frac{1}{6}$.

There is no equality of ratios, and hence there is no proportion.

LESSON III.

I. Terms.

"What is the ratio of 3 to 2?" $\frac{2}{3}$ or $1\frac{1}{2}$.
"What is the ratio of 6 to 4?" $\frac{6}{4}$ or $1\frac{1}{2}$.
The ratios being equal, we have this proportion—

$$3 : 2 :: 6 : 4$$

Tell the children that the numbers which form the proportion are called *terms*, and they are named 1*st*, 2*nd*, 3*rd*, and 4*th*, in the order in which they are placed.

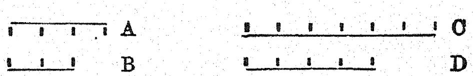
Thus—1st term : 2nd term :: 3rd term : 4th term.

The 1st and 4th are called *extreme* terms, and the 2nd and 3rd are the *mean* terms.

II. The product of the extremes equals the product of the means.

The teacher may show this by taking any number of actual examples, or by some such method as the following :—

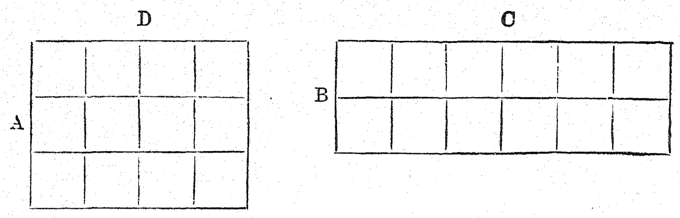
Draw lines A, B, C, D.



Thus A represents 3 units, B 2, C 6, and D 4.

Then A : B :: C : D, because 3 : 2 :: 6 : 4.

Next draw two parallelograms with sides A and D and B C respectively.



The parallelogram A D is equal in area to the parallelogram B C. Note that the length of the sides A and D are the two *extremes* in the above proportion, and B and C the two *means.*

Show that these figures are equal in area, each containing 12 equal squares.

The parallelogram formed by the lines which represent the *extremes* has the same area as the parallelogram formed by the lines which represent the *means.*

$$3 \times 4 = 12 \text{ and } 6 \times 2 = 12$$

Where proportion exists the product of the extremes is equal to the product of the means.

An example.

If 24 yds. of cloth cost 96s., what must I pay for 19 yds. at the same rate?

Here the first ratio is—

$$24 \text{ yds.} : 19 \text{ yds.} = \frac{24}{19}$$

And the second ratio is—

$$96\text{s.} : x\,\text{s.} = \frac{96}{\;}$$

And $\frac{24}{19} = \frac{96}{x}$, or the terms would not be in proportion.

We may write the proportion—

$$24 : 19 :: 96 : x$$
$$\text{Or } 19 : 24 :: x : 96$$
$$\text{And } 24x = 96 \times 19$$
$$\therefore x = \frac{96 \times 19}{24} = 76\text{s.}$$

III. Given three terms of a proportion, to find the fourth term.

Take the proportion $3 : 4 :: 6 : 8$.

(1.) To find the *first* term. Put x to represent it.

$$\text{Then } x : 4 :: 6 : 8$$
$$\text{,, } 8x = 24$$
$$x = 3$$

(2.) To find second term—

$$3 : x :: 6 : 8$$
$$6x = 24$$
$$x = 4$$

(3.) To find third term—

$$3 : 4 :: x : 8$$
$$4x = 24$$
$$x = 6$$

(4.) To find fourth term—

$$3 : 4 :: 6 : x$$
$$3x = 24$$
$$x = 8$$

LESSON IV.

The teacher may further illustrate the idea of proportion in a variety of ways.

The following are sugggestions:—

(1.) Rates are paid in proportion to the yearly value of the house.

Value of large house	:	Value of small house	::	large rate	:	small rate
£100	:	£20	::	£5	:	£1

(2.) The value of men's work being equal, wages are paid in proportion to time worked.

longer time	:	smaller time	::	larger wage	:	smaller wage
20 dys.	:	5 dys.	::	£5	:	£1$\frac{1}{4}$

(3.) We say men are *well* or *ill* proportioned. What does this mean? We have an ideal in our minds which pleases the eye, and with this we compare. Say, for instance, that a 6-foot man has an arm which measures 32 inches, and this to the eye is a pleasing ratio (72 ins. : 32 ins).

Then a man measuring 5 feet 3 inches (or 63 ins.), should have an arm 28 inches long to be in the same pleasing ratio :—

For 72 ins. : 32 ins. :: 63 ins. : 28 ins.

Suppose the arm of second man to measure 30 inches, then we should say it is too long for the body or the body too short for the arm; the lengths of the body and the arms are *not well proportioned.*

(4.) This kind of comparison is of constant recurrence.

(*a.*) Size of clothing must be proportioned to the size of the wearer.

(*b.*) Work assigned must be proportioned to the strengh of the worker.

(*c.*) The strength of different parts of the bodies of animals is proportioned to the work they have to do. The neck of the elephant, for instance, is proportioned to the size and weight of the head it has to carry, and the work the trunk has to perform.

(*d.*) The empire of man over the brute force of the lower animals is proportioned not to his strength, but to the knowledge he possesses of their respective constitutions.

(*e.*) In architecture there must be a just proportion between the parts.

(*f.*) In sculpture, and in painting, there must be a just proportion of the several parts to one another and the whole.

If further elucidation is necessary, the proportional compasses will be a good subject for another lesson.

FIFTH STAGE.

FIFTH STAGE.

LESSON I.

FORCE.

ARTICLES for illustration: a glass tube and pith ball and a piece of silk, or a magnet and iron filings.

I. Definition of force.

Exp. 164. Rub a dry glass rod briskly with a warm silk handkerchief, and then present one end to a pith* ball suspended by means of a silk thread. The ball is at first drawn towards the rod, but after touching it is pushed away.

Exp. 165. Or, strew a few iron filings on a sheet of paper placed over a bar, or horseshoe, magnet. The filings arrange themselves in lines diverging from the ends of the magnet.

Now what causes the pith ball, or the iron filings to move? To this question we can give no satisfactory answer. We know that the objects move, and we are quite certain there must be a *cause;* but there our knowledge ceases. This cause we call a *force.*

When a body *moves* we know there must be a cause, and when a body in *motion* is brought to *rest* we know there must be a cause. When there is a *change* in the motion of a body there must be a cause. When a body is held in a particular *position* we know there must be a cause.

* Cut from the pith of a branch of the elder-tree.

We attribute motion, and rest, and change, and position to some *force*.

Force is that which can produce, change, or destroy motion.

II. Kinds of forces previously described.

Having demonstrated in this simple way what we mean when we speak of *force*, the teacher will assist the children to recall to their minds such forces as have been described in preceding lessons. These are :—

1. Force of cohesion.
2. Force of adhesion.
3. Force of capillary attraction.
4. Force of gravity.

A few questions will serve to refresh the memory on the chief points connected with cohesion, adhesion, and capillary attraction; but before proceeding to deal with another force—the chemical force—it will be well now to explain the phenomenon of gravitation a little more fully.

III. Attraction of gravitation.

It is a law of nature, so far as we know, that all bodies, great and small, attract each other; and, if they are free to move, will move towards each other with increasing swiftness until they meet.

Thus (Fig. 65) A and B are balls of equal size and

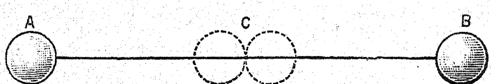


Fig. 65.

weight. Hence they attract with equal force, and would meet at C, a point midway between them, if there were no preventing cause.

But the fact is the earth attracts the balls, and being so many times larger attracts with so much greater force that

the balls have no power to move except towards the earth. And this is the case generally. It is not that the earth simply draws all bodies on its surface to itself; but that all bodies pull the earth towards themselves just as the earth pulls them. Only that the earth is so many millions of times larger than the largest body on its surface, that the effect of the pull of the latter cannot be felt or measured. It is as though an elephant were pulling at one end of a rope and a fly at the other.

[It may be interesting to the children to learn the rapidity or *velocity* of a body moving towards the earth. It moves through 16 feet in the first second: for every succeeding second it moves with a greater velocity. In the second second it travels $3 \times 16 = 48$ feet, in the third second $5 \times 16 = 80$ feet, in the fourth second $7 \times 16 = 112$ feet, and so on. If a stone be dropped from the top of a tower and it occupies two seconds in falling, the height is $2 \times 2 \times 16$. If three seconds $3 \times 3 \times 16$. If four seconds $4 \times 4 \times 16$, and so on.]

LESSON II.

CHEMICAL ATTRACTION.

ARTICLES for illustration: the articles will, of course, depend on the experiments selected. The first experiment is the most striking, but it requires a little care.

Exp. 166. Place "flowers" of sulphur in a small flask, and drop in a few bright copper shavings. Heat the mixture over the spirit-lamp; but place the whole apparatus in a pan or tub with a little water at the bottom in case the flask should break.

Heat gently. The sulphur melts, then blackens and boils. The copper now becomes red hot, when the lamp

may be removed. The copper and sulphur unite together to form an entirely *new substance*, giving off intense light and heat in the process.

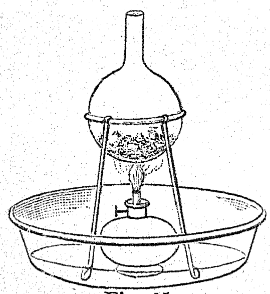


Fig. 65.

Exp. 167. On a small bit of phosphorus* place a few grains of iodine. The two combine and burn with a smoky flame.

Exp. 168. Pass carbonic acid gas through lime-water (see Lesson XIII., page 60). The gas combines with the lime in the water to make chalk, which sinks to the bottom as a white powder.

Exp. 169. Put a small piece of the metal sodium on water in a broad shallow vessel. The metal becomes spherical in shape and runs about over the water but gets less and less until it finally disappears. The metal takes something from the water, of which we shall learn more in a future lesson; and forms with it a new substance which dissolves in the water.

Exp. 170. Mix ammonia gas with hydrochloric acid gas (see Lesson VII., page 49); a new substance is formed quite different from either of the gases.

From one or more of these experiments, *or from some similar experiments*, the teacher will lead the children to see that some substances have such an *attraction* for each other that when placed together they unite to form a separate and distinct substance. Here, then, we have another *force*, which is called *chemical affinity*, or *chemical attraction*. When placed close together under favourable circumstances many substances unite to form others.

In the first experiment heat had to be applied to start the combination of the sulphur and copper, and we may say

* Phosphorus should always be kept under water. When a small piece has to be cut off hold the stick with wet blotting-paper.

generally that heat brings about and promotes the chemical combination of substances.

Sometimes, however, heat will separate the substances which are joined to form another substance.

Exp. 171. Heat a little of the red oxide of mercury in a test-tube. A gas is given off, whose presence is detected by the re-kindling of a glowing chip of wood placed in the tube, and liquid mercury is left behind.

LESSON III.

ELEMENTS AND COMPOUNDS.

ARTICLES for illustration: dioxide of manganese, hydrochloric acid, copper foil, or powdered antimony.

I. Elements and compounds compared with letters and words.

The children will most readily grasp the meaning of *elements* and *compounds* in the language of chemistry by a comparison with the *letters* and *words* of our written language.

Take a page of any book; no matter how many *words* it contains, there can be no more than twenty-six *letters* in the page. So of the whole book; there may be thousands of words, but they are all built up of two or more of the twenty-six letters of the alphabet.

Again, some of these letters are used *very often*, others *very seldom*. For instance the letters, *o*, *a*, *e*, &c., are constantly recurring, whereas the letters *z*, *x*, and *q*, occur but seldom.

Again, the *same* letters arranged in different order make *different* words.

Lastly, words vary in the *number* of letters which form them, from two or three up to a dozen or more; but the larger number of words are formed of the smaller number of letters.

Now if we call the letters of the alphabet the *elements* of our written language, we may call words the *compounds*, because they are built up or compounded of the letters.

The various substances—solid, liquid, and gaseous—which form nature's great book—the world—are like words. They are, for the most part, built up of *simple substances* which cannot, at present at least, be divided into any other substances. These are the letters, or the *elements*.

Letters are joined to form *words;* so *elements* combine to form *compounds*. There are twenty-six letters in the alphabet. Nature's alphabet consists of about sixty-four elements.

The letters *a* and *I* may stand alone; some of the elements, too, stand alone. They exist free and uncombined, as *mercury* and *sulphur*.

Some of the letters are in common use, others occur but rarely; so of the elements some are very common, others are very scarce and are but seldom seen.

Some of our words are built of two letters, others of three, four, or five, and so on; so some of the compounds consist of two elements, others of three, others of five, six, or seven, and so on.

Many of our words of two or more syllables are made up of shorter words; and so new compounds may be formed by the union of other compounds.

The compounds bear no likeness whatever to the elements of which they are composed. Instance the experiment with sulphur and copper filings in the last lesson; or the invisible gas and the liquid metal which were got from a red powder.

II. The very common elements.

The teacher should make a table of the very common *elements* for future reference.*

* ELEMENTS.

Gases	Non-Metallic	Metallic	
oxygen	carbon	iron	copper
nitrogen	sulphur	lead	gold
hydrogen		tin	silver
chlorine		mercury	zinc

II. Illustrations.

Further to illustrate the formation of compounds having properties absolutely different from their combining elements, the teacher may make the following experiment.

1. To make chlorine gas.

Fit up apparatus as shown in Fig. 66. Put in a little

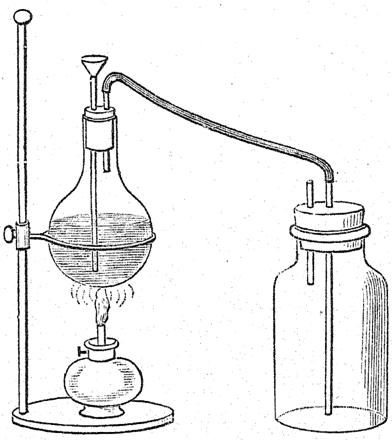


Fig 66.

strong hydrochloric acid and rinse it round the flask. Remove the cork, and put in a few lumps of dioxide of manganese.

Pour in through the funnel strong hydrochloric acid sufficient to cover the manganese. Heat gently. Collect the gas in a dry bottle. It cannot be conveniently collected over water because water readily dissolves it. When the bottle is full, which may be seen by the greenish yellow colour of the gas, remove the flask from the room and cover the jar quickly with a greased glass plate, as the gas is very irritating when breathed.

Now we have a jar of chlorine gas, one of the elements. It is a heavy gas. We know this because it displaces the air in the jar. It has a greenish yellow colour.

Remove the cover and insert a leaf or two of "Dutch" gold-leaf, or thin copper leaf; the leaf ignites and burns with a smoky flame. If powdered antimony be thrown in bright sparks will appear.

In the first case the compound, chloride of copper, is formed; and, in the second case, chloride of antimony; and these bear no likeness whatever to the elements of which they are made. When substances unite chemically they produce new bodies entirely different from themselves. If possible show one of these "salts"—chloride of copper or antimony—for the purpose of comparing the properties of a compound and of its elements.

LESSON IV.

THE AIR A MIXTURE OF GASES.

ARTICLES for illustration: apparatus and materials for making oxygen, piece of thin iron wire, and a lump of lead or other heavy body.

I. Oxygen.

Exp. 172. Heat potassium chlorate, to which about one-fourth of its weight of black oxide of manganese has been added, in a retort; and, after allowing sufficient time for the air to be expelled, collect the gas which comes off.

The colourless gas which we collect is called oxygen. It is heavier than air for we can collect it as we collected chlorine by displacement.

But its most important property is that bodies burn more readily in it than in air.

Exp. 173. Ignite a splinter of wood, extinguish the flame, leaving only a red spark. Plunge into a jar of oxygen, and the splinter bursts into flame at once, and burns more brightly and much more freely than in air.

Exp. 174. Take a fresh bottle of gas and pour in a little

water just to cover the bottom. Coil about a foot or eighteen inches of very fine iron wire round a piece of glass tubing, so as to form a spiral. Remove the wire from the rod, fix one end in a cork which just fits the neck of the bottle, and to the other end fix a bit of wax taper.

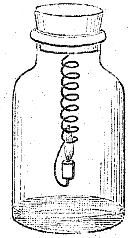


Fig. 67.

Ignite the taper and immerse the whole in the oxygen (Fig. 67). The taper ignites the wire, and beautiful bright sparks fly off in every direction.

If convenient the teacher may give other experiments to show this special property of *supporting combustion*.

II. Nitrogen.

Exp. 175. Fix a short piece of wax taper on a lump of lead and place in a shallow vessel. Pour in sufficient water just to cover the lead. Ignite the taper and cover it with a bottle inverted, as in the cut (Fig. 68).

The taper burns brightly for a short time, but gradually gets dim, flickers and dies out. At the same time the water rises, filling about one-fifth of the bottle

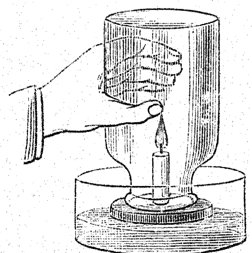


Fig. 68.

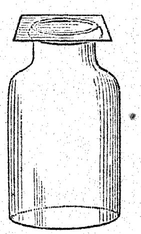


Fig. 69.

Slip the bottle off the lead into the water, remove the lead, and slide a piece of greased glass over the mouth of the bottle and invert (Fig. 69).

If a lighted splinter of wood is now plunged into the bottle, the flame is immediately extinguished.

The teacher will now explain that we burned away all the oxygen, and that there is still a gas left behind. This gas we call *nitrogen.*

The active property of oxygen should next be compared with the negative property of nitrogen, and the quantity, by volume, of oxygen and nitrogen in the air should be deduced from the quantity of nitrogen—four-fifths—left in the bottle.

III. Composition of the atmosphere.

Lastly, the teacher will recall to the minds of the children that there are also small quantities of carbonic acid gas* in the air; and a larger, but varying, quantity of aqueous vapour. These gases are all mixed together in the atmosphere as we can mix sand and sugar. They are not chemically combined, like mercury and oxygen in the red oxide of mercury.

A mixture may be distinguished from a compound by the fact that each element in the mixture keeps manifestly its own properties, and does not merge them in those of a different substance. The oxygen of the air is *diluted* in nitrogen like brandy in water. But it keeps its properties just the same.

LESSON V.

WATER A COMPOUND OF TWO GASES.

ARTICLES for illustration: apparatus and materials for making hydrogen gas.

I. Hydrogen.

Exp. 176. Put some pieces of granulated zinc in the bottle (Fig. 70). Cover the zinc with water and add

* About four parts in one thousand.

sulphuric acid through the funnel. Hydrogen is given off, and issues through the short glass tube.* At first it is mixed with air. Allow a few minutes for all the air to be expelled,† and then ignite the hydrogen.

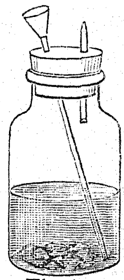


Fig. 70.

The gas burns with a blue flame which gives off great heat, but very little light.

Hydrogen may be collected by displacement, only in this case the bottle must be inverted and the gas poured upwards, because of its exceeding lightness. Hydrogen has about one-fourteenth the weight of air.

Fill a bottle in this way and thrust up into it a lighted taper. The gas ignites at the mouth of the bottle, but the taper is extinguished when it is surrounded by the gas.

The teacher should here compare the different action of a bottle of oxygen gas. Hydrogen burns when in contact with the air or with oxygen; but puts out a lighted taper plunged into it. Oxygen does not burn at all; but a taper plunged into it burns more brightly than in air.

We may say, then, that oxygen supports combustion, but is not itself combustible; and that hydrogen is itself combustible, but does not support combustion.

II. Water.

Hold over the flame a cold dry glass vessel. It soon becomes covered with moisture. Why is this? The *burning* of the hydrogen is just a *union* of the *elements*, oxygen and hydrogen, to form the *compound* water. This water rises as steam, and condenses on the cold glass.

The teacher may illustrate the intense *chemical attraction* which exists between oxygen and hydrogen by exploding a mixture in a soda-water bottle.

* The tube is drawn out to a fine point or jet.

† N.B.—A mixture of air and hydrogen explodes, and hence a lighted taper should never be brought near until we are quite sure the whole of the air has been forced out of the bottle.

Exp. 177. Fill the bottle with water, and over the pneumatic trough allow hydrogen to expel two-thirds of the water, and oxygen the remaining one-third. The bottle will then contain a mixture of hydrogen and oxygen in the proportion of two to one. Wrap a duster round the bottle, remove from the water, and apply quickly a lighted taper. A smart explosion follows. The gases combine, and form water.*

LESSON VI.

COMBUSTION.

ARTICLES for illustration: rust of iron, and charcoal or other articles to show combustion.

I. Meaning of combustion.

We saw in the last lesson how freely oxygen and hydrogen unite, and that in the act of combination they give off heat and light. Bodies which, when they combine, give off light and heat are said to undergo *combustion.* Or to put it in another way, we give the name combustion to the union of two or more substances when in the act of combination they give off light and heat.

We say that hydrogen burns, but it burns only when it can combine with oxygen, as in the air. It would not burn in a bottle of carbonic acid gas for instance. Oxygen does not burn in the air, because it cannot combine with itself, or with the nitrogen mixed with it in the air. But oxygen causes combustion in an atmosphere of hydrogen, just as hydrogen burns in oxygen.

In nature, however, oxygen is found free everywhere, whilst hydrogen is never found uncombined, and so it comes about that when we speak of combustion in common language, we always mean the combination of some body or

* If the teacher can command the apparatus for decomposing water, he will be able still bett r to show the composition of water.

other with oxygen. Oxygen, therefore, is said to support combustion.

Sometimes in chemistry the word combustion is used in a wider sense. Thus the oxygen of the air combines with iron, and forms a reddish-brown powder which we call *rust*, and the iron is said to be slowly *consumed*, although it gives off no light and no appreciable heat.

[Show the rust of iron and compare its properties with those of its elements, iron and oxygen.]

Again, the oxygen of the air taken into the body through the lungs combines with the waste matter, and in the act of combination gives off heat. This *combustion* of the waste matter is the source of all the heat of the body.

II. The common products of combustion.

We have said that charcoal, or *carbon*, is an element. What do we mean when we say that charcoal burns? We mean that it combines with the oxygen of the air, and that in the act of combination it gives off heat and light. And what new compound does it form? If we burn charcoal in oxygen over lime-water we shall find that the water becomes milky, showing that the compound is the carbonic acid gas described in a former lesson. You may remember that carbonic acid gas is harmful to breathe in large quantities, and sometimes people have committed suicide by shutting themselves in a close room, and breathing the fumes of burning charcoal.

A large part of our coal, and wood, and oil, and coal gas consists of carbon, and hence wherever these are burned carbonic acid gas is made.

When hydrogen was burned we saw that water was made, and a large part of our fuel and lights being composed of hydrogen in combination with carbon, or with carbon and oxygen, whenever we have a fire or a light from oil or gas we are manufacturing water. *Carbonic acid gas* and *water*, then, are the two chief products of combustion.

LESSON VII.

THE CHEMISTRY OF A CANDLE.

ARTICLES for illustration: a candle, and stem of a "clay" tobacco-pipe.

I. The candle.

Refer to Second Stage, Lesson XV., page 64, on candles.

Question as to what substances are used in the manufacture of candles.

Tell the children that all fats and oils are made up of various compounds of carbon and hydrogen, or of carbon, hydrogen, and a smaller quantity of oxygen. The common fats classed under the name of tallow contain the *three elements*. Paraffin and paraffin oil contain no oxygen. The *wick* is made up of carbon, hydrogen, and oxygen, with a little earthy matter.

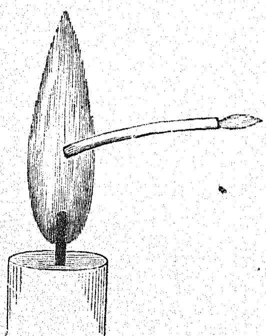


Fig. 71.

II. How a candle burns.

Light the candle; call attention to the cup of melted tallow, then to the ascent of the liquid fat up the wick by capillary attraction. The children may see the flow upwards. When the liquid fat reaches the flame it is changed by the heat to gas. It is the gas which burns. Show this by putting one end of the stem of a "clay" pipe into the centre of the flame (Fig. 71). A portion of the gas escapes through the pipe and may be ignited at the other end.

III. Structure of the flame.

Now look at a *steady* candle-flame* very carefully side-

* The candle may be placed in a wide chimney-glass, but of course open to the air below.

ways. In the inside a dark zone is easily detected. This is simply a zone, as we have shown, of unburnt tallow-gas. Next, and surrounding this central zone, is the very bright or *luminous* zone. Here, for the *most part*, the hydrogen of the gas combines with the oxygen of the air. This chemical union produces an intense heat, which causes the tiny particles of carbon to glow, and in fact produce the light. Outside this *light-producing* zone there is a more abundant supply of oxygen, and combustion is complete. This outside zone is therefore very hot, but yields less light.

The candle-flame then consists of three parts: a dark central zone of gas to which the oxygen of the air cannot penetrate, and which therefore is not burning; a second or light-producing zone enveloping the first, where some oxygen penetrates, and where the particles of carbon are raised to white heat before themselves undergoing complete combustion; and a third, or heat zone, again enveloping the luminous zone, where combustion is complete.

We can show the threefold structure of the flame in another way. Press a sheet of white paper, held horizontally, into the flame of a candle almost down to the wick. Retain in that position for a second or two. Remove and note the effect on the paper. A black ring of carbon, in the shape of fine soot, is shown; outside this there is another ring of lighter shade where less carbon is deposited, and within the ring a light deposit of soot is shown.

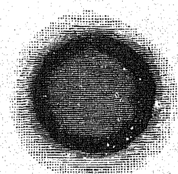


Fig. 72.

This deposit of a dark and two light rings of carbon is easily explained. The dark ring corresponds to the luminous zone where there is abundance of carbon at a white heat. The outer light ring corresponds to the heat zone, where combustion is more complete and consequently there is less carbon to deposit.

The carbon *within* the dark ring is deposited as we press

the paper down through the flame. That the inner zone deposits no carbon may be shown by directing the jet from the pipe (Fig. 72) on to a sheet of paper.

LESSON VIII.

ELECTRIC AND MAGNETIC FORCES.

ARTICLES for illustration: strips of copper and zinc, piece of copper wire, sulphuric acid, iron filings, a magnet, a thread of silk untwisted and a sewing needle.

I. Electric force.

Exp. 178. Take a strip of zinc plate about 4 inches long and an inch in width and place in a glass (Fig. 73) containing dilute sulphuric acid.

Direct the children to notice the result. There is formed a collection of bubbles on the surface of the zinc. These break away, rise to the surface of the liquid, and are dispelled in the air. Then other bubbles take their places. Now what causes these bubbles, and of what gas do they consist? Refer back to the lesson on hydrogen. How is hydrogen prepared? These bubbles then are hydrogen gas. We can collect and burn them.

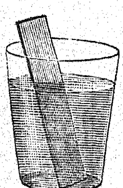


Fig. 73.

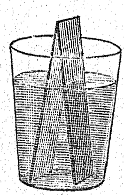


Fig. 74.

Next put a strip of copper of similar size into the dilute acid and without touching the zinc. Are bubbles formed on the copper? No, only on the zinc. Now lean the strips of zinc and copper against each other as in Fig. 74, and note the result. Torrents of bubbles rise from the copper, and but very few from the zinc. It will be found after awhile that the zinc is worn away, but that the copper is left intact, notwithstanding that the bubbles rise from the copper.

The same effect follows when the plates are connected by a wire instead of being placed in contact. Break the wire, and bubbles no longer rise from the copper.

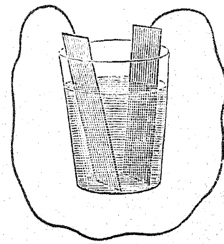


Fig. 75.

We may conclude from these experiments that there must be some connection between the metals to bring about the particular action we have noted. Unless the wires are connected the particular action does not occur; hence it seems that some influence is exerted by the metals upon one another through the wire.

Exp. 179. Suspend a magnetized sewing needle* by a fine untwisted silk thread. The needle will point practically north and south. Now carry the wire connecting the plates under and parallel to the needle as in Fig. 76. The needle turns on its axis and tends to place itself at a right angle to the wire.

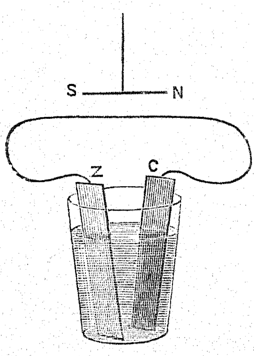


Fig. 76.

Here, then, we have another *force* which we have not before considered. It is called the *electric force*, and is closely allied to another force referred to in Lesson I. of this stage—the magnetic force.

II. Electric and magnetic forces connected.

Exp. 180. Take a magnet and plunge it into iron filings. Note the result.

Now wrap a piece of paper round a piece of thick iron wire—a six-inch French nail will answer very well—leaving the ends free, and then wind around it twenty or thirty

* To make a magnet of the needle, draw it several times across one end of a magnet from end to end and always in the same direction, not backwards and forwards.

turns of copper wire, keeping the coils from touching each other. Connect the ends of the iron wire with the zinc and copper plates, and plunge one end of the wire into iron filings. The wire has becomes a magnet which attracts the filings just as the magnet did. The electric force in the wire imparts to the iron another force—a magnetic force —precisely similar to the force exercised by the magnet. When the contact between the plates is broken the wire ceases to act as a magnet. Its force is gone.

It is sufficient for our purpose here to show that there are two other forces of nature very closely allied beyond those already described. It is of course in the discretion of the teacher to pursue the subject furthcr as opportunity may offer.

LESSON IX.

CENTRE OF GRAVITY.

ARTICLES for illustration: water-bottle, couple of forks, a few wheat-straws without flaw, and some blocks of wood.

The teacher should introduce the subject of this lesson by a reference to Lesson I. on gravity, viz. pressure downwards, or weight. Place say a pound weight in the hand of one of the scholars. He experiences a pressure downwards. What is this pressure? A pound. Now with what force must he press upwards to keep the weight from falling? Clearly one pound.

I. To find the centre of gravity.

Exp. 181. Now *balance* a slate horizontally on the thumb of the left hand. What force does the thumb exert in an upward direction? A force equal to the pressure of the slate downwards, viz. its weight.

In the case of the slate every particle of it presses downward in a perpendicular direction (Fig 77).

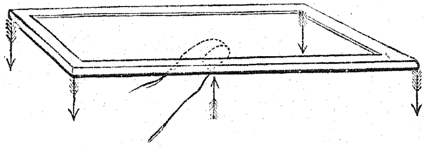


Fig. 77.

The pressure upwards is collected in one point, the top of the thumb, and this point supports the whole weight of the slate. We can imagine the whole weight of the slate to be collected at the point supported by the thumb, for when that point is supported the whole slate is supported. If the thumb be placed on any other point the slate is not *balanced*, and falls to the ground. We may call the point where the whole weight of the slate is supported the *centre of weight*, or as it is more commonly called, the *centre of gravity*.

In the case of the slate, which is of regular geometrical form, we can find the point by drawing lines diagonally from corner to corner. The point where the lines cross is the *centre of gravity*.

In this case we have not considered the thickness of the slate; but suppose the slate to have a thickness of half an inch, then the exact *centre of weight* will be a quarter of an inch from the surface, but in a vertical line above the point supported by the thumb. If, therefore, we wish to support any body, we must be careful to apply the support directly under or above the *centre of gravity*.

Another method of finding the centre of gravity of a body is by suspension. Take the slate once more. Suspend it from any point, say a corner. Draw a perpendicular line, found by improvising a plumb-line of a piece of fine twine and a weight. Suspend from another point, say a second corner, and draw a second perpendicular line. The point

where the lines cross will be the centre of gravity; and if a fine hole were drilled through the slate at this point it

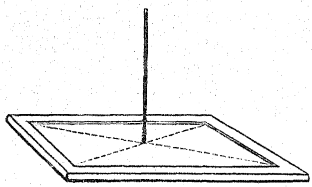


Fig. 78.

might be suspended in a horizontal position by means of a piece of string (Fig. 78).

A bottle of water may be supported by a single bent straw (Fig. 79). The straw is bent before being placed in the bottle, so that when the bottle is lifted the centre of gravity is displaced and brought directly under the point of suspension.

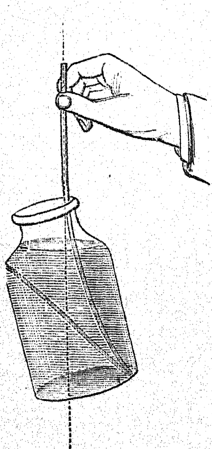


Fig. 79.

II. When the centre of gravity of any body is supported, that body cannot fall.

Take two blocks of wood cut as in Fig. 80. In (1) the line of direction A B falls within the base of support; hence the centre of gravity is supported and the block does not fall.

In (2) the line of direction C D falls without the base of support, and the block cannot stand in the position indicated.

A picture of the "leaning tower of Pisa" might here be exhibited. And it might here be explained that the reason why the tower has stood safely for hundreds of years is that, as in the case of block (1) Fig. 80, a perpendicular line from the centre of gravity falls within the base.

The teacher should now assist the children in pointing out how men and animals are continually shifting the position of their centres of gravity to bring them within their bases of support. A man in carrying a weight on his back leans forward, a nurse carrying a baby leans backward ; a man carrying a bucket in one hand leans toward the other, and stretches out the other arm to preserve his balance.

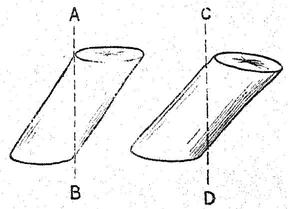


Fig. 80.

It must be borne in mind that the base of support is not necessarily limited to that part of the under surface of a body which rest on its support. Thus the base of support of a man resting on two feet includes not only the space actually covered by the feet, but also the space between the feet.

One other point with reference to the centre of gravity remains to be considered, viz. *that the lower the centre of gravity lies the more stable is the body ;* that is, the less easily can the body be overturned.

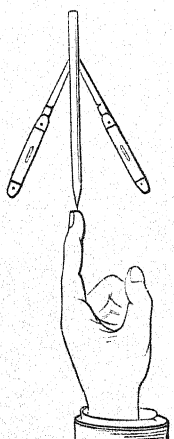


Fig. 81.

It is not easy to balance a lead pencil on the point of the finger, but if weights be attached as in Fig. 81 the centre of gravity is brought below the point of support, and the pencil is supported without difficulty.

In ships and boats the centre of gravity is brought as low as possible by putting heavy ballast in the bottom.

Exp. 182. A curious and interesting experiment to further illustrate this fact may be arranged as in Fig. 82.

Fix two forks in a cork, and into the bottom of the cork insert a sewing needle. On the neck of a bottle place a coin

—a half-crown or a penny. Balance the forks as shown in the figure. The contrivance may be made to revolve without destroying the equilibrium. The centre of gravity here is somewhere in an exact line with the needle but considerably below it. This line we have called *the line of direction.*

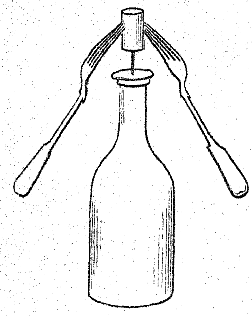


Fig. 82.

The teacher may now ask such test questions as the following:—

1. Why does a person in rising from a chair bend forward?

2. Why is it more difficult to overthrow a man when he is standing with his feet some distance apart than when his feet are placed close together?

3. Is there any advantage in turning out the toes when we walk?

4. A man stands with one side close to a perpendicular wall; why cannot he hold up the other leg from the ground?

5. Why cannot a man standing with his back and feet close to a wall stoop to pick up anything in front?

6. How far may a wall be made to lean and yet stand securely?

To make the following lessons on *Simple Machines* or the *Mechanical Powers* effective, the teacher will need working models. Their being rough and commonplace will not detract from their value as working illustrations.

LESSON X.

LEVERS AND THEIR USES. I.

The teacher should introduce the subject of the simple

machines by questioning the children on such of them as they must have seen in their everyday rambles. The pulley used for raising building materials on to the scaffold; the ladder up and down which casks are rolled, or pushed into or from waggons; levers used for lifting bodies too heavy for the unaided arms, and so on.

I. First order of lever.

The model lever* should next be introduced, and its parts described.

The pin on which the lever turns is called the *fulcrum*, F. The body to be raised is called the *weight*, W, and the force applied at the other end of the lever to raise the weight is called the *power*, P.

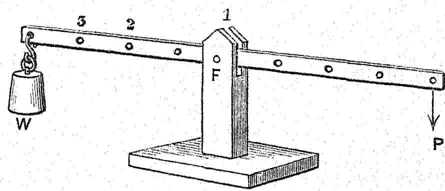


Fig. 84.

The parts of the lever on each side of the fulcrum are called the *arms*.

Under the teacher's guidance, the children should discover for themselves all the facts useful for them to know about the lever.

1. Place equal weights, one at the end of each arm. Note the result. They balance. What advantage is there in a lever so arranged? Suppose the weight to be 30 lbs., and we have to raise it one foot. 30 lbs. would be heavy for a boy to lift. But if fastened to one end of the lever he might sit on the other, and so raise the weight without exertion.

* The lever may consist of a bar of stiff wood about 4 feet in length through which several holes are drilled, as in Fig. 84. The stand may consist of a *base* made of inch deal board 15 inches by 8 or 9, and an *upright* made of 4-inch quartering. A groove must be cut in the quartering at top to allow of free motion to the bar, Fig. 83, A. A hole is drilled through for the pin on which the lever turns, Fig. 83, B.

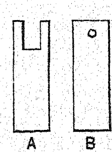


Fig. 83.

The advantage is in changing the direction of the *force.* In pushing or pulling *downwards* we are assisted by the weight of our bodies.

2. Remove the weight, take out the pin and shift the lever one foot to the right, the pin to go through the hole marked 2 in the Fig. One arm will now be 1 foot long, and the other 3 feet. Now make the weight 3 lbs., and attach 1 lb. to the end of the long arm. Again note the result. 1 lb. at the end of the long arm rather overbalances 3 lbs. at the end of the short arm. If the lever had no weight it would exactly balance.

3. Arrange the lever so that the long arm shall measure 3 feet 6 inches, and the short arm 6 inches. It will be found that 1 lb. at the end of the long arm will overbalance 7 lbs. at the end of the short arm.

From these experiments the children will readily grasp this principle, that *the longer the "power-arm" is in comparison with the "weight-arm," the greater is the weight we can raise with a given power.*

The teacher may also go a step beyond this, and show that —neglecting the weight of the lever—*the weight multiplied into its distance from the fulcrum is equal to the power multiplied into its distance from the fulcrum.*

Or weight : power : : length of power arm : length of weight arm.

II. Examples.

Common examples of this kind of lever may now be brought under review.

1. Ordinary scales for weighing. In this machine the arms are of *equal* length, and a pound on one side balances a pound on the other.

2. The child's *see-saw.* Note, if one child is heavier than the other, how the arms have to be arranged.

3. The common steel-yard (Fig. 85), another machine for

weighing goods, is a lever of the kind described, but with one arm longer than the other. Question on the proportion between P and W in the steel-yard.

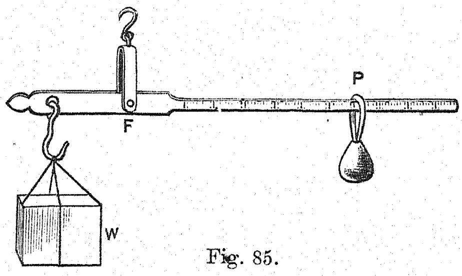


Fig. 85.

4. Another example of the use of the lever is illustrated in Fig. 86.

5. The poker used in stirring the fire, the small trucks used by porters at railway stations for picking up luggage, the ordinary pump-handle, and the claw-hammer are other examples of this lever.

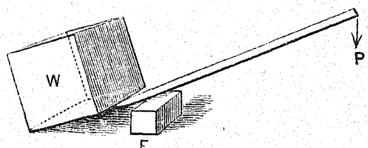


Fig. 86.

Lastly, the children should be informed that the particular arrangement of the lever in which the power is at one end, the weight at the other, and the fulcrum between the two, is called *a lever of the first class, or first order.*

LESSON XI.

LEVERS AND THEIR USES.—2.

I. Lever of the Second Order.

We now proceed to consider the lever used in another way. Shift the lever so that the fulcrum is at one end (Fig. 87),

and the power P at the other. If a pound weight be placed on the end of the lever at P it is quite clear that, to keep the lever in its horizontal position, we must pull upwards with a force of 1 lb. in addition to the force required to support the lever.

Now shift the weight to the centre of the bar. In this

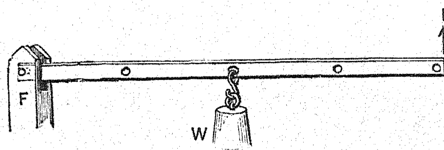


Fig. 87.

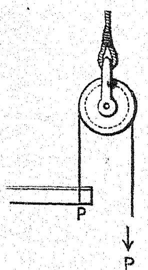


Fig. 88.

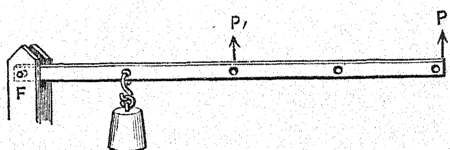


Fig. 89.

position the upward force at P must be half a pound, as the fulcrum supports the other half. This may be tested by passing a line from P over a small pulley suspended from above, and affixing a half-pound weight * (Fig. 88).

Again, shift the weight to the distance of one foot from the fulcrum (Fig. 89). What upward force must be exerted at P to support the weight in this position?

Suppose for the moment the power to be applied at the centre of the lever at P′; in that position, omitting the weight of the lever, the upward force must be half a pound. But a force at P equal to a quarter of a pound acting in an opposite direction, will balance a force at P′ of half a pound. Hence a quarter pound force at P will support 1lb. at a distance of one foot from the fulcrum.

Allowing a little for the weight of the lever, experiment will show the truth of this statement.

* Some extra weight will be required to support the lever itself.

From the above experiments the teacher will again be able to deduce—

1. *That the longer the power-arm is in proportion to the weight-arm, the greater is the weight we can raise with a given power.*

2. *That the weight multiplied by its distance from the fulcrum is equal to the power multiplied by its distance from the fulcrum.*

II. Examples.

Common examples of this lever :—

1. The wheelbarrow. The wheel is the fulcrum, the load in the barrow the weight, and the man lifting the handles the power.

2. A boat oar. The water is the fulcrum, the boat the weight, while the power is applied by the hand.

3. A chopping knife turning on a fulcrum at one end is another example.

4. Nutcrackers and cork-squeezers are double levers of this kind.

The children may now be told that when a lever is so arranged that the fulcrum is at one end, the power at the other, and the weight in the middle, it is said to be of the *second class* or *order*.

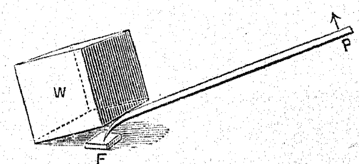


Fig. 90.

Fig. 90 shows how a lever of the second class is sometimes used.

LESSON XII.

LEVERS AND THEIR USES.—3.

I. Lever of the Third Order.

We now come to a lever having a different arrangement again. It is called the lever of the *third class* or *order*.

The fulcrum is at one end of the lever as in the *second* kind; but in this case the weight is at the other end, and the power is applied somewhere between the fulcrum and the weight (Fig. 91).

It will be found on trial, viz. by passing the string by which the power is applied over a pulley, that if the power

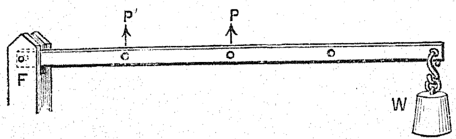


Fig. 91.

is applied in the centre of the lever, it will require a 2 lb. weight to support 1 lb. at the end of the lever.

The teacher may show that this must be the case from the lever of the second kind. Suppose the weight W of 1 lb. to be arranged to pull the lever upwards, then it will *balance* a weight of 2 lbs. at P. Or, which is the same thing, a power equal to 2 lbs. in weight applied at P in one direction will balance a weight of 1 lb. applied at W in the opposite direction.

In the same way the teacher may show that it will require a power equal to 4 lbs applied at P′ to support a weight of 1 lb. at W.

The second and third kinds of lever are identical, except that the power in one case takes the place of the weight in the other.

In the lever of the third kind it will be seen that the power is always greater than the weight. Where, then, is the advantage? The advantage is that the weight is moved through a greater space, and of course at greater speed, than the power. This may be shown by experiment.

In this case also *the power multiplied into its distance from the fulcrum is equal to the weight multiplied into its distance from the fulcrum.*

II. Examples.

Levers of this kind are less common than the others. A good illustration will be to direct a boy to hold a weight in a long-handled shovel or in a spade.

One hand, usually the right, acts as the fulcrum, the other hand furnishes the power which lifts or balances the weight.*

A man raising a board, a pole, or a ladder with one end pressed against the bottom of a wall or held by a second person is another example which may be illustrated in the schoolroom. [Note, when the raising commences the lever is of the second kind, and so remains until the man gets below the centre of gravity of the article he is raising.]

In the mechanism of the human body there are many examples of levers of the third kind. The arm may be taken as the most simple for illustration. The socket of

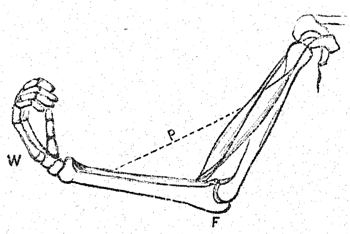


Fig. 92.

the elbow joint forms the fulcrum, the biceps muscle is the power, and the weight is the forearm and anything supported by it.

A pair of tongs is an example of a *double* lever of this kind.

* A fishing-rod held with both hands forms a similar example.

LESSON XIII.

THE PULLEY.*

I. Single Fixed Pulley.

From the lever of the first kind to the pulley is an easy transition.

Fasten a short lever (see foot-note), to work on a screw as a pivot on the side of the pulley-stand (Fig. 94). Show how the lever works. The arms are of equal lengths and the weight and power must be equal. There will be just as hard a pull in one cord as in the other. This pull or strain is usually described as the *tension.*

Now substitute for the lever a disc of deal board having a diameter equal to the whole length of the lever (Fig. 95).

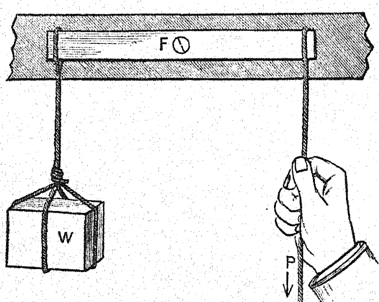


Fig. 94.

It turns on the screw as a fulcrum, as in the case of the lever. Fasten the cords to the disc at A and B. This machine is nothing more nor less than a lever of the first kind.

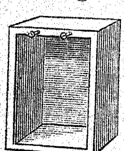


Fig. 93.

* The side of a deal table or an old box stood on end and with the lid removed, will serve as a pulley-stand. Insert a couple of screws on which to hang the pulleys or fasten the cord.

Next take a longer cord and pass it over the pulley. The necessity for the groove round the circumference is at once apparent. By this apparatus we can raise the weight as high as the pulley is fixed, but as the arms of the lever are of equal length the power must equal the weight. That is, if we want to raise 1 cwt. we must pull down with a force of 1 cwt.

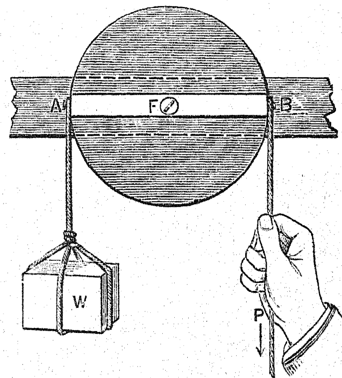


Fig. 95.

This revolving lever with arms of equal length is called a *pulley*.

Show the scholars that the advantages of this pulley are (1) *direction* in the application of the power, and (2) we can raise the weight to any desired height.

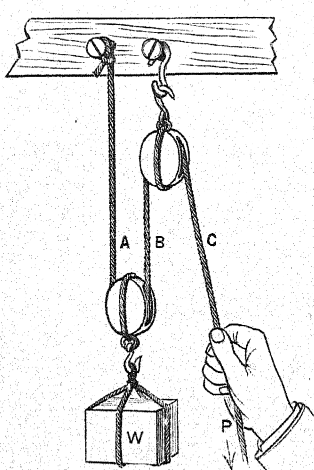


Fig. 96.

II. A Fixed and Movable Pulley.

The teacher will now fit up a couple of pulleys,* one fixed and one movable as in Fig. 96, and then proceed to show the advantage of this system of pulleys. Suppose the weight W to be 8 lbs. The cord A B passes round the movable pulley and supports the weight; hence the tension or strain in each part of the cord is the same. What is this tension? To find this we refer back to a lever of the second kind.

* Block pulleys may be purchased at quite a small cost.

We may suppose two props (Fig. 97) to support a weight of 8 lbs. between them. Clearly each prop will support half the weight, viz. 4 lbs. Just in the same way each part of the cord supports half the weight, and the tension is 4 lbs.

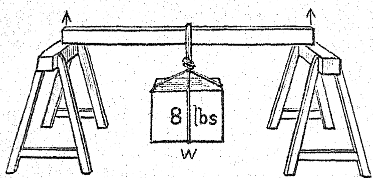


Fig. 97.

The tension of the cord marked B is 4 lbs., and the tension in the cord C must also be 4 lb., for in the fixed pulley we have seen that we gain no mechanical advantage; the weight and the power are equal.

The teacher will deduce from the above that, when there are two pulleys, one fixed and one movable, the weight is double the power—that is, to raise 2 cwt. a power equal to 1 cwt. only is required. In practice this is not quite true, for we have to take into account the weight of the movable pulley and the cord.

III. Three or more Pulleys.

The children may next be shown by a blackboard sketch (Fig. 98), the advantage of using a greater number of pulleys.

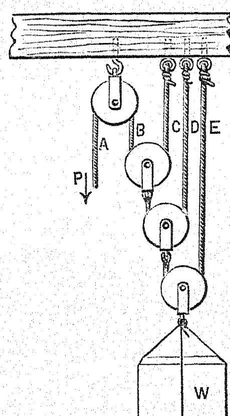


Fig. 98.

Suppose the cord A has a tension, or pull downwards, of 1 cwt.; then B and C will each pull upwards with a force of 1 cwt. each, viz. pulley No. 1 will be supporting a weight of 2 cwt.

The tension in F and D being 2 cwt., the pulley No. 2 will support a weight of 4 cwt.

In the same way pulley No. 3 will support a weight of 8 cwt.

For each movable pulley the weight capable of being raised is doubled.

In practice a considerable portion of the power is expended in raising the pulleys and in overcoming friction.*

The teacher may lastly show that here, as in the lever, what we gain in weight we lose in space and time.

LESSON XIV.

THE WHEEL AND AXLE.

The principle of the wheel and axle, a combination of the lever and the pulley, may be shown by using the disc of the last lesson (see Fig. 99).

Fix the weight by the cord at A, and attach a strip of wood

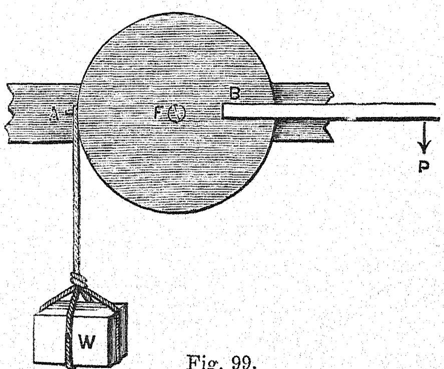


Fig. 99.

at B. By trial find out what weight suspended at the end of the long arm F P of the lever will support a given weight, W, at the end of the short arm A F.

At present our machine is a lever of the first kind.

Given that our wheel is arranged to work horizontally, and the groove widened to take a number of coils of the cord, and the cord lengthened to the extent required, we have the wheel and axle as used on board ship for raising the anchor (Fig. 100).

* See Lesson XVIII.

Show the scholars how this is practically a large wheel and a small one, the circumference of the larger wheel being the

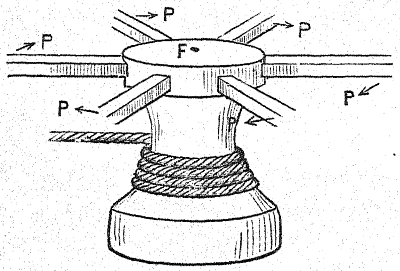


Fig. 100.

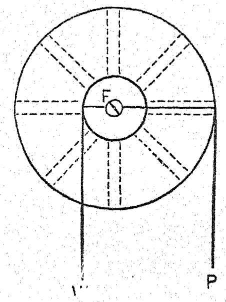


Fig. 101.

path made by the end of the spokes, and the part of the axle which receives the cord the smaller wheel.

We may use a wheel with a groove instead of the spokes, and then, placed in a perpendicular direction (Fig. 101), we see the machine as used in another way.

It would not be difficult for the teacher to illustrate this by a rough model* as shown in Fig. 102 and to show that if

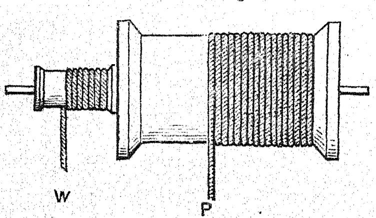


Fig. 102.

the radius of the larger wheel is 3 inches and of the smaller 1 inch, a weight of 1 lb. placed at P will balance a weight of 3 lbs. placed at W.

Note that the cord round the large wheel or axle is wound in a contrary direction to that round the small axle

* One large and one small cotton-reel fastened together answer very well.

Sometimes instead of the large axle a handle is used. This is the case in the common *windlass* for raising water out of wells. (See Fig. 103.)

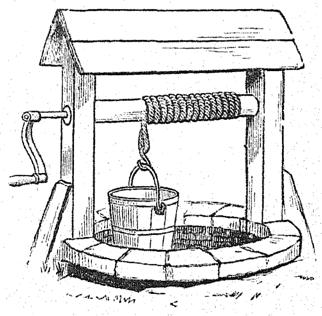


Fig. 103.

The teacher will show here again that the centre of the axle is the fulcrum, the radius of the axle the short arm, and the radius of the circle described by the handle the long arm of the lever, and from these calculate the power requisite to raise a given weight.

LESSON XV.

THE INCLINED PLANE.

The teacher may introduce this lesson by some questions on the way in which brewers' men raise the barrels into their waggons, and on the comparative amount of force required to carry a load of equal weight up a hill with a gentle slope, or up another with a steep slope, walking at the same pace in each case.

To carry a load up the gentle ascent will be the easier task. Why, and by how much?

To answer these questions in the most satisfactory way, the teacher must construct an inclined plane and affix a pulley at the top (Fig. 104).

It will be found on trial that a weight of, say 5 lbs., acting downwards from the pulley will support a weight of 10 lbs. on the inclined plane when (1) the string from the weight to the pulley is parallel to the plane, and (2), when the length of the plane A B is double the height A C.

We should have expected this to be the case from the

principle that "what is gained in weight is lost in space and time." Here the weight has to travel over *twice* the length it would have to travel over supposing it to be lifted perpendicularly from C to A.

When the length of the plane is three times the height,

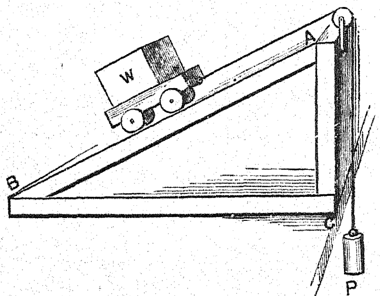


Fig. 104.

the power required to balance the weight will be one-third the weight; when the plane is four times the height, the power required is one-fourth the weight, and so on.

In actual practice, to raise a weight on the inclined plane the power must be somewhat greater than the proportion here given, because there is friction to overcome. It will be sufficient if the scholars thoroughly master the fact that the longer we make the inclined plane the easier it is to raise a given weight.

When very heavy casks have to be rolled up an inclined plane another contrivance is sometimes adopted. Two ropes are fastened at the top of the plane, then laid along the plane to the bottom and passed round the cask and doubled back to the top of the plane. This may be imitated in a small inclined plane by passing a couple of pieces of twine round a piece of lead tube.

In this case the teacher will show that the power has to move through twice the distance, and that consequently twice the weight can be raised by a given power. The apparatus constitutes in fact a single movable pulley, and

the tension in each cord is half that of the tension in a single cord as in Fig. 104.

Two ropes are used for convenience ; they keep the cask in proper position for rolling, but no further advantage is gained over the use of one rope.

LESSON XVI.

THE WEDGE.

Take a piece of wood cut in the shape of an inclined plane, and show how it can be used for raising a weight on the table by pushing the plane under the weight instead of pushing or pulling the weight up the inclined plane (Fig.

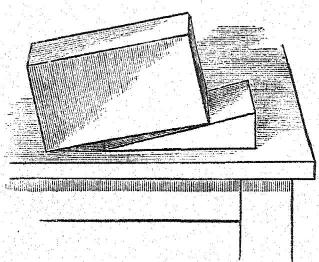


Fig. 105.

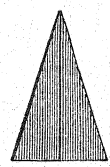


Fig. 106.

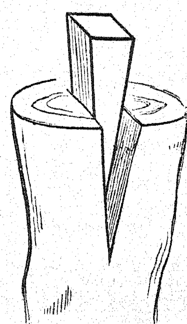


Fig. 107.

105) ; in fact, making the inclined plane a *movable* instead of a *fixed* machine.

Secondly take another inclined plane of the same shape and size as the former ; place the two base to base (Fig. 106), and use them to raise the weight just in the same way as with the single inclined plane.

Tell the children that the double inclined plane is called a wedge. Show its use for splitting wood by a sketch on the blackboard (Fig. 107).

The power applied in the case of the wedge is not a simple pull or a push, but a sharp blow with a hammer or mallet, the force of which we cannot measure;* neither in most cases can we measure the force of resistance to the entry of the wedge. Hence, all the teacher need to impress on the children is that we gain a great mechanical advantage by using this machine, as we do in using others.

The teacher will lastly refer to common forms of the wedge and their uses, such as a knife, a nail, the prongs of a digging fork, a ploughshare, a needle, a pin, &c.

LESSON XVII.

THE SCREW.

The screw, like the wedge, is a movable inclined plane; but in this case the inclined plane is wrapped round a cylinder.

This can be shown very readily.

Take a piece of white flexible cardboard. Cut from it a *long* and *low* inclined plane. Colour the edge of the plane, and wrap round a cylinder (Fig. 108). [The size of the cylinder must depend to some extent on the length of the inclined plane, but the whole should be as large as possible.]

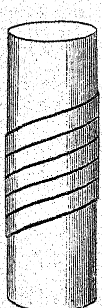


Fig. 108.

The children will be able to see from this experiment the likeness of the coloured line formed by the coloured edge of the plane to the thread of the screw.

Next take a large screw of some kind (Fig. 109)—wood or iron—and let the children trace the easy ascent of some supposed living insect round and round the

* Let P = power, and R resistance, b = length of *half the back* of the wedge, l = length of wedge; then $P : R :: b : l$.

cylinder, but up and up the inclined plane from the bottom to the top.

Refer to spiral staircases constructed on a similar plan.

It is not often that the inclined plane wound round a cylinder is used as a fixed machine for raising bodies; on

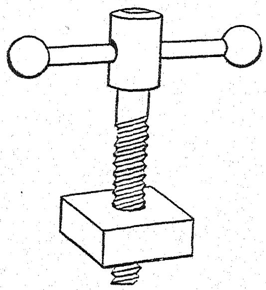


Fig. 109.

the contrary, it is nearly always used as a movable machine for penetration, or for squeezing and holding together.

In "presses" for pressing very hard, long and powerful levers are employed to turn the screw. Fig. 110 represents

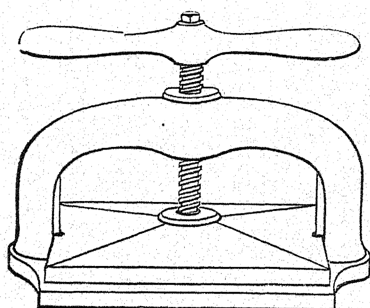


Fig. 110.

a copying-press with two levers.

The pressure in a machine of this sort is very great. By looking at one turn of the screw unrolled we shall get some idea of the power (Fig. 111).

Let the height of the inclined plane, or, which is the same thing, the distance between one thread and the next, be one-eighth of an inch, and the length of the inclined plane, viz. the circumference of the cylinder, be three inches or

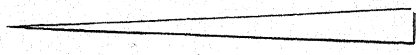


Fig. 111.

twenty-four eighths ; then the weight (in this case the pressure downward) will be twenty-four times the power.

The children will understand that when we use a lever to turn the screw, the force with which the screw presses downwards will be immensely increased, and they may be told, just to illustrate the power of presses, that the machine is now practically an inclined plane whose height is the distance between the threads and whose length is the circumference of the circle described by the lever.

Let this circumference be 6 feet, viz. 72 inches, or 576 eighths of inches, and the distance between the threads one-eighth of an inch ; then a pressure of 10 lbs. at the end of the lever would produce, if there were no friction, a pressure below the screw of 5760 lbs., or more than $2\frac{1}{2}$ tons. Practically the pressure is much less.

The common screw for joining wood or iron work, the corkscrew, and gimlet, are all examples of the "screw."

LESSON XVIII.

FRICTION.

In the preceding lessons on the simple machines the term friction has been once or twice used. What is friction ? And what effect has friction on bodies moving one over another ?

Take a block of rough wood and call on one of the scholars to press it along over a rough board. The boy has to exert considerable force to slide the block along. Now let him slide a polished block along a polished table. The force required is much less. Over smooth ice or a sheet of glass it would be less still.

The *resistance* which the moving block meets with from the surface on which it moves is called *friction*.

Boys cannot slide any distance on a road, however level, but they can make long slides on the ice. Why? The friction is less on the ice. It is difficult to walk on ice; we are liable to slip and fall because the friction is slight. But strew ashes or sand over the ice, the friction is increased and we can walk at ease. In frosty weather sand is thrown over the streets to keep the horses from falling.

In taking heavy loads in waggons down steep hills, the driver fastens an iron shoe on one wheel to keep it from turning round. The friction between the shoe and the road is great. It prevents the waggon from moving so freely and eases the horse. Sometimes "breaks" are applied to carriage wheels. The friction between the break and the wheel hinders the wheel from turning so freely.

When masons want to move large blocks of stone, they

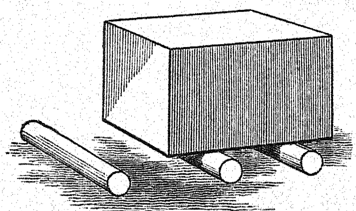


Fig. 112.

put rollers under them to lessen the friction (Fig. 112). The teacher may illustrate this by putting a heavy body on two or three "round" rulers.

It is the friction between the road and the wheel which makes the wheel turn. Take the railway train, for instance. The steam moves the piston, and the piston, by means of complicated machinery, moves the large "driving wheels;" but if there were no friction between the wheel and the iron rail the wheel would simply turn round and not roll forward. The wheels would not *bite*, as people say.

Sometimes in frosty weather it is difficult to start or stop the train because the rails are so slippery—that is, there is little friction—and sand is thrown on the metals to increase the friction. The wheel, of course, turns on an axle, and here we want no friction, because all friction here tends to hinder motion, and so the axles are kept well greased or oiled. So of carriages and waggons, that part of the axle on which the wheel turns is kept well greased to lessen the friction.

Friction is not confined to solid substances. Rocks over which water constantly flows are worn away by friction. It is by friction that the wind raises the waves on the water, and it is by friction that the air causes a corn-field to assume a wavy motion.

Wherever there is motion on the earth it is more or less retarded by friction.

INDEX.

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